DET NORSKE SKOGFORSØKSVESEN, VOLLEBEKK, NORGE

CONRAD BONNEVIE-SVENDSEN
and
ODD GJEMS

# Amount and Chemical Composition of the Litter from Larch, Beech, Norway Spruce and Scots Pine Stands and Its Effect on the Soil

*Mengde og kjemisk sammensetning av strøet i lerke-, bøke-, gran- og furubestand og dets virkning på jordbunnen*

# Contents.

## Foreword.

These investigations are a direct continuation of a smaller-scale investigation in 1948—49 of a stand of Larix leptolepis and a stand of Fagus silvatica at Ås, Norway. The results were so interesting that the work was continued, so that the material now under consideration is from five additional plots.

Contributions to these investigations have been received from the Scientific Research Fund for the Agricultural College of Norway, and from the Forestry and Forest Industries' Research Organisation.

The utmost goodwill has been shown by the forest owners and the personnel with whom we have been in contact during the choice of the plots, and the planning and execution of the experiments.

Throughout the work, we have had valuable guidance from Professor Dr. J. Låg and Professor Dr. Elias Mork.

The chemical analyses have been performed partly by the authors, and partly by the chemical technicians Miss Emma Aagaard and Mr. Magne Opem.

The translation from Norwegian to English is undertaken by Mrs. D. M. Johnsen.

We wish to convey our best thanks to all those who, by means of discussion or in other ways, have been of assistance to us in this work.

Vollebekk, April 1956.

## I. Introduction and Description of Problem.

Work on the question of the detrimental effect on the soil resulting from the removal of litter was begun in Germany in the middle of the last century. In this connection, investigations were made as to the quantity of litter contributed annually to forest soil. Since then, a long list of investigations has taken place all over the world regarding the litter-producing capacity of the various species of tree, and the influence exerted upon the soil by this litter. In spite of the fact that until quite recently there have been few reliable results from these experiments, certain species have been classed as «soil-improving», others as «raw humus-forming» or «soil deteriorating».

The impression is gained that an appraisal of the influence of the various species of tree on the soil is in many instances dependent upon the particular site upon which the investigations have been carried out. Beech, for example, has in many cases been given the name «The mother of the forest», whereas in other cases it is known as «Raw humus-producer of the worst type». (RUBNER 1932, TÜXEN 1932). Larch is often regarded as a very beneficial type of tree, whith a nutritious, easily decomposable litter, (ALBERT 1928, HESSELMAN 1926), while later experiments, both in field (WITTICH 1933, 1936, 1939, 1943, 1944) and in laboratories (MIKOLA 1954, VIRO 1955) show that the decomposition of larch needles takes place very slowly.

Norway spruce is generaly regarded as a soil-deteriorating type of tree, especially in Central Europe, where it is cultivated to a large extent in areas which are unsuitable (KRAUSS et al. 1939). The labile brown earth in the south of Sweden also seems to deteriorate under Norway spruce, as well as under beech, in that the soil in Norway spruce and beech stands is often subject to podzolization (TAMM 1930). For Norway spruce within its natural area of development (with raw humus and podzol), and in areas where the soil is not liable to

deteriorate, there seems to be no reason for anxiety regarding a progressive deterioration of the soil (HARTMANN 1932, WIEDEMANN 1951).

In Central Europe, Scots pine is also regarded as an injurious type of tree, and more harmful than Norway spruce as far as the litter is concerned. WITTICH (1939) finds that Scots pine needles decompose more slowly than Norway spruce needles. MIKOLA (1954) has, however, both by experiments in the laboratory and out in the stand, found that pine needles decompose rapidly, even more rapidly than birch leaves.

MATTSON and KOUTLER-ANDERSSON (1941), in laboratory experiments during the course of one year, have found the same speed of decomposition for Norway spruce and Scots pine, while the figures for beech are somewhat lower, and those for birch slightly higher.

The reasons for these somewhat contradictory results can be numerous. Laboratory experiments are carried out in various ways, and the litter which is used in the experiments is obtained from different sites and shows a varying chemical content, for example with regard to the nutrients calcium and nitrogen.

The influence of the site upon the decomposition of beech leaves and Scots pine needles seems quite clear, according to WITTICH (1939). The loss of dry matter after eight months varies for Scots pine from 27.5 % to 48.1 %, for beech from 25.5 % to 45.6 %. He found the lowest rate of decomposition for needles and leaves which were collected in stands on chalk-free soil, and the highest from stands on soils rich in chalk. WITTICH himself does not seem to attach any significance to this fact, but concludes that the collection site is without significance for the decomposition.

The field experiments also must, naturally enough, be influenced by the conditions prevailing at the plot. These conditions can, to a certain extent, alter the sequence of the various tree species (WITTICH 1953).

As it may be very misleading to draw parallels for our own country with results and experience from other parts of the world, we have, with these experiments, tried to illuminate the question more closely by means of comparable plots in different parts of eastern Norway.

In all places, except Ås, plots of Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus silvestris* L.) have been laid out in adjacent stands for purposes of comparison.

The following tree species have been investigated: — *Larix sibirica* Ledeb., in Østreng forest, Eidsberg; in Ringsaker Prestegårdsskog, Ringsaker; and at Øvergård, Koppang, in Storelvdal.

*Larix decidua* Mill., in Grue Prestegårdsskog, Grue.

*Larix leptolepis* (Sieb. & Zucc.) Gord., in Åkebakke forest, Ås.

*Fagus silvatica L.,* In Fritzøehus park (near Larvik), at Brunlanes, and in Åkebakke forest, Ås.

It has sometimes been difficult to find suitable stands, but we have tried as far as possible to find areas where the soil and the site class were similar for the stands which were compared at the same place. At some places, it was not possible to avoid a slight admixture of other tree species in the stand under investigation.

The investigations cover the years 1951—52 and 1952—53, and at Ås also 1948—49. Their object can briefly be summarised as follows:—

1. What quantities of litter are produced yearly by beech and larch?
2. What is the nutrient content of this litter?
3. How quickly does it decompose?
4. What effect has the litter from larch and beech on the soil?
5. How do the above-mentioned conditions for larch and beech compare with our usual tree species, Norway spruce and Scots pine?

The various categories of litter which are treated in this work are given the following definitions (MORK 1942):

1. *Forest litter* is all the organic material which is supplied to the soil from the trees during the course of the year. This has been divided into:—

a. *Main litter,* consisting of needles or leaves from the main tree species in the stand under investigation.
b. *Residual litter,* comprising all other litter from the main tree species (twigs, cones, bark, etc.)
c. *Other litter,* which is forest litter not originating from the main tree species.

2. *Ground litter* is litter from the ground vegetation.

## II. Description of the plots and the individual stands.

In table 1, an outline is given of the description of the plots, and in table 2 a description is given of the investigated stands.

### 1. Grue Prestegårdsskog, Grue.

The tree species investigated here were *Larix decidua* and *Picea abies.* The plots lie approximately 250 m. above sea level, on a rather shallow moraine with a large boulder content. The site class lies be-

tween 2 and 3 according to the Norwegian Forest Survey classification (mean annual increment 6.5—4.1 $m^3$ per hectare).

In the case of both species the conditions of the stands made it necessary to set out the collection pots in two groups.

The larch stand was planted in 1862, and is therefore approximately 90 years old. The trees are of large dimension, but are rather unevenly spaced on account of windfalls. The Norwegian Forest Research Institute has sample plots in both stands, and the material from these forms the basis for the volumes given.

In one stand, there are 232 trees per hectare, with a volume of approximately 230 $m^3$, and in the other stand 239 trees, with approximately 320 $m^3$ per hectare.

The field has a slight to medium incline towards north and west. The ground vegetation is more or less uniform, being for the most part common moss, consisting of *Hylocomium* and *Dicranum* species, as well as *Ptilium crista-castrensis*. In addition, there are a number of fresher patches with *Vaccinium myrtillus,* some *Lastrea dryopteris (Dryopteris linnaeana) Majanthemum bifolium, Oxalis acetosella* and *Deschampsia flexuosa*. The spruce stand is approximately 80 years old. No exact calculation of the volume has been taken, but we have made an estimate by means of the relascope and height measurements. One stand has approximately 210 $m^3$ per hectare, the other approximately 150 $m^3$ per hectare.

In many instances, the covering in these stands is found to consist solely of moss, including the *Hylocomium* species, and a certain amount of *Dicranum* and *Ptilium crista-castrensis. Vaccinium myrtillus, Lastrea dryopteris* and *Deschampsia flexuosa* also occur.

### 2. Østreng forest, Eidsberg.

The plots lie on the south-east slope of a large marginal moraine terrace, approximately 150 m. above sea level.

The tree species which are investigated here are *Larix sibirica* and *Picea abies*. Both stands are planted on previously cultivated soil, and are of good site class 1 (mean annual increment 9.2 $m^3$ per hectare).

The Norwegian Forest Research Institute has sample plots in both stands, and both the volume and increment data are calculated on the basis of material from these stands.

The larch was planted in 1909 on ground with a slight incline towards the south. There has previously been a certain amount of

Table 1. *Description of the plots.*

| *Plot, county* | *Geographic position* | *Height above sea level in metres* | *Bedrock* | *Soil description* | | | *Tree species* |
|---|---|---|---|---|---|---|---|
| | | | | *Soil type* | *Soil material* | *Soil texture* | |
| Grue, Hedmark | Lat. N. 60° 29′<br>Long. E. 12° 06′ | 250 | Pre-Eocambrian rocks | Iron podzol | Morainic soil material rich in boulders | Slightly clayey coarse fine sand. Clayey coarse fine sand | Larix decidua<br>Picea abies |
| Eidsberg, Østfold Østfold | Lat. N. 59° 34′<br>Long. E. 11° 18′ | 150 | Pre-Eocambrian rocks | Brown earth | Marginal delta, the „Ra" | Sandy clay. Clayey very fine sand | Larix sibirica<br>Picea abies |
| Ringsaker, Hedmark | Lat. N. 60° 54′<br>Long. E. 10° 43′ | 170 | Boundary Cambro-Silurian rocks/ Eocambrian rocks | Brown earth | Morainic soil material | Clayey coarse fine sand | Larix sibirica<br>Picea abies |
| Storelvdal, Hedmark | Lat. N. 61° 34′<br>Long. E. 11° 02′ | 330 | Eocambrian rocks | Iron podzol | Stream terrace | Clay-free medium sand. Slightly clayey medium sand | Larix sibirica<br>Pinus silvestris<br>Picea abies |
| Brunlanes, Vestfold | Lat. N. 59° 03′<br>Long. E. 9° 59′ | 50 | Permian plutonic rocks of the Oslo Region | Transition podzol-brown earth | Morainic soil material | Clayey medium sand. Clayey coarse sand | Fagus silvatica<br>Picea abies |
| Ås, Akershus | Lat. N. 59° 40′<br>Long. E. 10° 46′ | 80 | Pre-Eocambrian rocks | Brown earth | Morainic soil material | Clayey fine sand<br>Clayey fine sand | Larix leptolepis<br>Fagus silvatica |

intermingling of Norway spruce and balsam fir, but most of these are now removed, and there are only a few widely spread spruce. On an average, there are 577 trees per hectare, with a volume of 206 $m^3$. The annual increment in 1951 was 11.8 $m^3$ per hectare.

The ground vegetation in this stand is quite luxuriant and rich. Of grasses, the most common are *Agrostis tenuis* and *Deschampsia caespitosa*. The most common herbs are *Oxalis acetosella, Majanthemum bifolium, Anemone nemorosa* and *Fragaria vesca*. The principal mosses are the usual *Hylocomium* species.

The Norway spruce stand was planted in 1903 on practically flat ground. There is no intermingling of other trees. There are 1087 trees per hectare, with a volume of 384 $m^3$. The increment in 1951 was approximately 16 $m^3$ per hectare.

The stand is very dense and the ground vegetation is rather sparse. Grass is found only as scattered blades. *Oxalis acetosella* has, on the other hand, a relatively high degree of coverage. No other herbs worthy of mention are found. Mosses have a very high degree of coverage, principally the usual *Hylocomium* species.

### 3. Ringsaker Prestegårdsskog, Ringsaker.

The plots lie adjacent to each other on a north slope with a medium incline, probably the proximal part of a terminal moraine. The height above sea level is approximately 170 m.

The investigated tree species were *Larix sibirica* and *Picea abies*.

The Norway spruce stand was rather uneven, so far as density, age and height are concerned. The oldest trees had, however, a dense inner core, and after several measurements it was decided that the stand could be regarded as more or less of even age physiologically, between 30—40 years old. With this as a basis, the site class here should be 1 (mean annual increment 9.2 $m^3$ per hectare).

The average number of trees per hectare in the stand is 1290, and the volume is approximately 160 $m^3$ per hectare.

The ground vegetation consists partly of *Lastrea dryopteris*, partly *Oxalis acetosella* and *Majanthemum bifolium*, and partly, especially in open spaces, *Pteridium aquilinum*. Otherwise, there is found a certain amount of grass and scattered *Vaccinium myrtillus*.

The mosses which occur most often are the common *Hylocomium* species, as well as some *Polytrichum comune*, which forms thick mats here and there.

Table 2. *Description of investigated stands.*

| Plot | Tree species | Site class | Age (years) | Number of trees per hectare | Basal area sq. m | Standing volume cub. m |
|---|---|---|---|---|---|---|
| Grue .......... | Larix decidua | 2–3 | 90 | 232–239 | 21–27 | 230–320 |
| | Picea abies | | 80 | – | 23–19 | 210–150 |
| Eidsberg ...... | Larix sibirica | >1 | 45 | 577 | 24 | 206 |
| | Picea abies | | 50 | 1087 | 36 | 384 |
| Ringsaker ...... | Larix sibirica | 1 | 35 | 917 | 26 | 227 |
| | Picea abies | | 30–40 | 1290 | 26 | 160 |
| Storelvdal ...... | Larix sibirica | 3–4 | 50 | 679 | 11 | 88 |
| | Pinus silvestris | | 90–130 | 1121 | 37 | 276 |
| Brunlanes ...... | Fagus silvatica | 1 | 80 | 679 | 25 | 242 |
| | Picea abies | | 45–65 | 841 | 31 | 248 |
| Ås ............ | Larix leptolepis | 1 | 30 | 1530 | 22 | 190 |
| | Fagus silvatica | | 25 | – | – | – |

It has not been possible to determine exactly when the larch was planted, but the stand is approximately 35 years old. Until a few years ago it was neglected, so that there is considerable unevenness with regard to dimension and height. The spacing also has become somewhat uneven. There are occasional examples of Norway spruce in the stand, and a few birch.

There are 917 trees per hectare, with a volume of 227 m$^3$. The annual increment has not been calculated, but it is undoubtedly considerable. The largest trees have a diameter at breast height of over 40 cm. and heights of 22—24 m.

The ground vegetation consists to a great extent of *Lastrea dryopteris* and various low herbs, with *Oxalis acetosella* and *Majanthemum bifolium* as the most common. A little dispersed grass is found, also *Vaccinium myrtillus* and a small quantity of moss.

### 4. Øvergård, Koppang in Storelvdal.

The tree species investigated here are *Larix sibirica* and *Pinus silvestris*. The plots lie on an almost flat stream terrace, approximately 33 m. above sea level.

The larch is planted in several smaller stands, and the collection pots are divided between two of these. In the case of Scots pine, the pots are set out in three smaller stands.

The age in the pine stands varies from 90 to about 130 years. The site class is considered to lie between 3 and 4 (mean annual increment 4.1—2.5 $m^3$ per hectare). There are 1 121 trees per hectare, and the volume is approximately 276 $m^3$.

The larch is 50 years old, or a little more, and shows signs of having been neglected over a long period. The crowns are narrow and the dimensions small. Here there is an average of 679 trees per hectare, with a volume of approximately 88 $m^3$.

The ground vegetation is more or less uniform throughout the area, and varies between lichen, and dwarf shrubs with patches of lichen. The dwarf shrubs consist mainly of *Vaccinium vitis-idaea*. In addition is found some *Calluna vulgaris*. The moss covering is principally *Hylocomium schreberi*, with patches of *Hylocomium splendens* and *Dicranum* species. The lichen species are mainly *Cladonia rangiferina* and *C. silvatica*, with a little *C. alpestris* and *Cetraria islandica*.

### 5. Fritzøehus park, Brunlanes.

The tree species under investigation here are *Fagus silvatica* and *Picea abies*. The stands are situated on a very boulder-rich and stony moraine. The plots lie about 50 m. above sea level. The site class and volume data are calculated on the basis of volume tables established for the district by Treschow-Fritzøe. The site class is assessed as 1 (mean annual increment 9.2 $m^3$ per hectare).

The experimental plot with beech has a gentle slope to the west. The stand is approximately 80 years old. There are 679 trees per hectare, with a volume of about 242 $m^3$.

The vegetation covering is quite thin. There is a little sparse *Vaccinium myrtillus*, a little *Deschampsia flexuosa* and *Luzula pilosa*. The quantity of moss is insignificant.

The Norway spruce stand is rather unevenly spaced, and for this reason only twenty collection pots were set out, divided into two groups.

The average number of trees is 841 per hectare, with a volume of approximately 248 $m^3$. The age varies from 45 to 65 years.

The ground vegetation consists of quite loose *Deschampsia flexuosa*, some *Luzula pilosa* and *Oxalis acetosella*. The moss covering is quite scanty, and consists for the most part of Dicranum.

### Åkebakke forest, Ås.

The plots lie very near each other, on gently sloping ground. The soil consists of ground moraine. Height above sea level is approximately 80 m., and the plot lies below the marine limit. The morainic material, therefore, shows signs of the action of the water.

The tree species investigated are *Larix leptolepis* and *Fagus silvatica*. The larch stand was planted in 1924, with three-year-old seedlings. There are about 1530 trees per hectare, and by means of relascope and height measurements the volume is estimated at approximately 190 $m^3$ per hectare. The site class is 1 (mean annual increment 9.2 $m^3$ per hectare).

The ground vegetation in the larch plot is not especially varied. The most frequent species are *Deschampsia flexuosa* and *Majanthemum bifolium*. Some *Deschampsia caespitosa, Lactuca muralis, Viola riviniana,* are also found, amongst other species. The principal mosses found are *Cirriphyllum piliferum* and *Eurynchium zetterstedtii*.

The beech stand was planted in 1928, also with three-year-old seedlings. The stand appears never to have been thinned, and the dimensions are quite small. We have, therefore, not calculated any volume for this plot.

On account of the high density, there is no ground vegetation of significance in this plot.

## III. Methods.

### 1. Field methods.

The collection of litter is achieved by means of collection pots. These pots were made of thin tin, 24 cm. high, and with a diameter of 21.4 cm. This corresponds to an opening of 363 $cm^2$.

In the plot, the pots were secured between two pegs, and placed as far as posible in a vertical position. A number of small holes were made in the base of each pot, so that rain and melted snow should not accumulate in them.

In the majority of the stands, 30 collection pots were placed in regular square spacing, five metres apart. Consideration was paid to the density of the stand, and the distance to its boundaries, and for these reasons, amongst others, it has been necessary in certain cases to divide the collection pots into groups. In the stands at Ås, wooden cases approximately 10 cm. high, with 0.1 $m^2$ opening, were used instead of tin pots.

With the exception of the plots at Ås, where the first investigations were carried out in 1948—49, the collection pots were set out during the course of the summer 1951. The experiments in the field were concluded two years later, in the summer of 1953. Unfortunately, some of the pots were disturbed, either by people or animals, and a number of them were destroyed; others simply disappeared during the experimental period. The number of these, however, is not so large that it is likely to affect the accuracy of the results.

In every stand four or five soil profiles are described, and soil samples were taken from all layers in every profile.

In every stand, except the beech plot at Ås, measurements and age estimates were taken as a basis for calculation of the volume and site class. In some cases, the Norwegian Forest Research Institute's measurements are used as a basis, in other cases the basal area is determined either by relascope measurement or by means of diameter measurements.

In an attempt to form an idea of the total amount of undecomposed main litter lying on the ground, small blocks of the litter residue and the upper part of the humus were cut, four or five from each stand. The blocks were exactly 0.1 $m^2$. These have also formed a basis for a partial evaluation of the ground vegetation's significance as a source of litter.

### 2. Pre-treatment of samples.

As the litter was collected, it was dried at room temperature. Each year's yield of litter in every pot was sorted into the three categories «main litter», «residual litter» and «other litter». Each category was then weighed separately for each pot. The samples were ground in Wiley's mill, and analysed. For the categories «residual litter» and «other litter» this was done simultaneously for each stand. The «main litter», however, was divided before grinding into groups according to the position of the pots in the stand. These groups were analysed separately, and used as units in the numerical treatment of the material.

The samples for the total quantity of main litter were also dried in the usual way, and the main litter segregated. All litter which was well preserved structurally was included here.

From the same samples, we have also tried to separate the ground vegetation litter, and this also was weighed and analysed.

Humus samples and soil samples were pre-treated by sieving them through a 2 mm. sieve.

### 3. Chemical analysis.

*Dry matter* was determined by drying the samples at 105° C.

*Loss on ignition* and *ash content* was determined by ashing the sample at 550° C.

*pH* was determined potensiometrically, using Radiometer PH 11 with glass electrode. The soil/water ratio was 1 : 2.5, for samples of raw humus the ratio was 1 : 5 to 1 : 10.

*Nitrogen* was determined by Kjeldahl's method. The sample was digested with sulphuric acid, copper sulphate being used as a catalyst. The ammonia was distilled off in an apparatus of the Parnas-Wagner model, and collected in 5 ml. 4 per cent. boric acid, to which had been added 30 ml. 0.1 per cent. bromcresolgreen and 10 ml. 0.2 per cent. methylred per litre. The ammonia was titrated with 1/140 N sulphuric acid. The change of colour is very sharp from green over greyblue to red.

*The litter.*

The silica was determined in the ash. The ash was taken up with dilute hydrochloric acid, after which the silica was filtered off and washed with dilute hydrochloric acid. The ignition was made in a porcelain crucible in an oven at 1 000° C., until constant weight. The values for silica obtained in this way may be 5—10 % too high, due to contaminations (WIJKSTRÖM 1935), but no attempt has been made here to correct this error.

The other ash components have been determined after digestion with nitric and perchloric acids.

0.5—1 grm. of the sample was treated overnight in a beaker with 10—20 ml. nitric and perchloric acid (1 : 2 by volume) on a hotplate at 60° C. (The beaker must be covered with a watchglass). The temperature was then gradually increased to 150° C. When the solution was colourless, the watchglass was removed, and the solution evaporated to dryness. The sample was then treated with dilute hydrochloric acid, and again evaporated to dryness. The residue was then dissolved in 10 ml. 1 N hydrochloric acid and filtered warm into a 100 ml. measuring flask. The filter was washed with warm water. When cold, the filtrate was made up to 100 ml. with water. From this stock solution, aliquots were taken for determination of potassium, calcium, magnesium, manganese and phosphorus.

*Potassium* was determined by the Perkin-Elmer Model 52A flamespectrophotometer, using lithium as «internal standard», and an

acetylene- air flame. Some of the determinations were carried out on a Beckman DU flamespectrophotometer using an acetylene-oxygen flame.

*Calcium, magnesium and manganese* were determined by complexometric titration with «Versenate» (disodiumethylendiaminetetraacetate) (GJEMS 1956).

1 grm. ammoniumchloride was added to 50 ml. of the stock solution, which was then neutralised with ammonia to the colour change of the indicator methylorange. Then 1 ml. cons. acetic acid was added. The solution was heated on a hotplate nearly to boiling, and 10 ml. 10 % ammoniumbenzoate was added to precipitate the sesquioxides (GJEMS and LYDERSEN 1954). The solution was allowed to boil gently for two to three minutes, and then quantitatively transfered to a 100 ml. measuring flask with warm 2 % ammoniumbenzoate. If convenient, the solution was allowed to stand overnight, and was then filtered through a loose filter (S. & S. 589[2]).

Calcium, magnesium and manganese were titrated with 0.004 M versenate, in suitable aliquots of the filtrate.

*Titration 1.* The sum of elements (calcium, magnesium and manganese) was titrated with Eriochromeblack T (241) as indicator after hydroxylamine had been added to prevent oxydation of manganese. The titration was carried out at pH 10, and potassiumcyanide was added to avoid interference by heavy metals.

A new aliquot (about 50 ml.) was taken in a separatory funnel, and a little solid hydroxylamine and about 100 mg. sodiumdiethyldithiocarbamate was added. The funnel was shaken by hand for about one minute, after which 15 ml. tetrachlorcarbon was added, and again the funnel was shaken for about ten seconds. After a few minutes, the lower layer was drained off, and the extraction with tetrachlorcarbon was repeated until the water layer was colourless (testing with more carbamate).

*Titration 2.* The sum of the elements calcium and magnesium was titrated in a suitable aliquot of the extract (CHENG et al. 1953).

*Titration 3.* Calcium was titrated in a new aliquot with murexide as indicator at pH 12 (CHENG and BRAY 1951).

The difference betwen titration 1 and 2 gives manganese, and the difference between titration 2 and 3 gives the content of magnesuim (in the aliquot).

The average difference between duplicated determinations has been almost the same for the three titrations when expresed in amount of versenate, viz. 0.03 ml. (or about one drop from the bu-

rette). This amount equals 0.005 mg. Ca, 0.003 mg. Mg and 0.007 mg. Mn.

*Phosphorus* was determined colorimetrically, according to SCHEEL (1935) (see also TAMM 1953).

The determinations have been made with a Schuhknecht-Weibel photometer, partly also with a Colleman jr. photometer.

*Soils.*

*Ammoniumchloride-soluble calcium* was determined according to MEYER (see KNUTSON 1948).

The sesquioxides (especially aluminium) were precipitated in the filtrate with ammoniumbenzoate, before the flamephotometric determination. (GJEMS and LYDERSEN 1954).

*Ammoniumchloride-soluble* potassium was determined flamephotometrically in the same extract as was used for calcium determination.

*Organic and inorganic phosphorus* was determined by the Damsgaard-Sørensen method (DAMSGAARD-SØRENSEN 1947).

Before the colorimetric determination of phosphorus by the Scheel method, an aliquot of the extract (0. 2 N sulphuric acid) was treated with nitric and sulphuric acid to ensure that the phosphates were present in the ortho-form (HERRMANN et al. 1943). This is especially important when the total phosphorus is determined after the dry ashing of the sample.

The content of organic phosphorus is the difference between total and inorganic phosphurus.

*Lactate-soluble phosphorus (L—figure)* was determined according to Egnér (EGNÉR et al. 1938).

*Monochloraceticacid-soluble potassium* (M-figure) was determined according to Egnér's method (EGNÉR 1940).

*Organic carbon* was determined by wet digestion with chromic and sulphuric acid in the van Slyke manometric apparatus (VAN SLYKE and FOLCH 1940).

*Texture* was determined by Tamm's method (TAMM 1934, TAMM and WADMAN 1945).

The dispersion of the samples was made according to Method A, (International Congress of Soil Science 1930).

## IV. Annual yield of forest litter.

EBERMEYER (1876) estimated throughout a number of years the quantity of litter in stands of Norway spruce, beech and Scots pine of various ages. On an average, he found a constant quantity of

litter for beech, a diminishing quantity for spruce, and an increasing quantity for pine, in proportion to the rising age of the stand. As the variations around the mean figures are very considerable, these tendencies for Norway spruce and Scots pine will not be significant. EBERMEYER found the average for beech to be 3331 kg., for spruce 3007 kg., and for pine 3186 kg. litter per hectare. These figures include also a quantity of residual litter, although the amount is not stated by EBERMEYER.

MORK (1942) has exhaustive measurements of the yield of litter in stands of Norway spruce, Scots pine and birch. In the case of spruce needles, he gives for two different stands the figures of 2400 kg. and 1500 kg. dry matter per hectare, and for a 200 years old pine stand in a mountain forest, 390 kg. needles per hectare.

LINDBERG and NORMING (1945) found in a stand of Norway spruce in the neighbourhood of Stockholm a main litter yield of 3089 kg. dry matter per hectare. The investigation lasted for one year.

BURGER (1945) has investigated a number of larch stands in Switzerland. In a 50 years old stand, 570 m. above sea level, he found an annual yield of needles amounting to 2600 kg. dry matter per hectare. A stand of 105 years, 1370 m. above sea level, produced 2250 kg., and one of 120 years, 1820 m. above sea level, 1830 kg. dry matter per hectare. The basal area for the three stands was respectively 45 $m^2$, 34 $m^2$ and 33 $m^2$ per hectare.

MØLLER (1945) found for beech in Denmark an average main litter yield of 2500 kg. dry matter per hectare. MØLLER asserts that the leaf quantity reaches nearly its maximum quite soon after the stand is closed, but shows in addition a slight increase (10—20 %) from the 20th to the 120th year. The leaf quantity remains quite constant with a highly varying thinning rate (from 35 to 18 $m^2$ basal area per hectare at 50 years of age). Only when the point is reached where the density of the stand begins to be broken decisively, there is a noticeable decrease in the leaf quantity.

A variation in the site class from 1 to 4 (Danish) exercises no demonstrable influence on the leaf quantity. (Site class 4 Danish corresponds approximately to the Norwegian site class 2, mean annual increment 6.5 $m^3$ per hectare).

The material in MØLLER's investigation is very considerable. For Norway spruce he has specified only the total needle quantity per hectare. The needle quantity seems, in the same way as the leaf quantity for beech, to be independent of the thinning rate, site class and

age. Also these investigations are limited to high site classes. It must also be borne in mind that the climatic conditions are very uniform.

Assuming that the needles remain on the branches for five years, MØLLER's figures for the total quantity of needles give an annual litter yield of 2400 kg. dry matter per hectare.

VIRO (1955) has investigated in Finland the monthly yield of litter, in, amongst others, stands of Norway spruce and Scots pine. The investigations included three spruce stands and three pine stands, and continued over one to four years. On the average, he found an annual main litter yield of 1830 kg. for spruce, and for pine 1505 kg. dry matter per hectare.

In table 3 we have set out the results of our measurements of litter production. In the case of Grue, we have had to abandon the results for 1952—53 on account of the disturbance of the collection pots. As will be seen from the table, the figures for the yield of main litter agree quite well with those quoted from previous investigations.

In an attempt to find a better basis for comparison between the various tree species, we have tried to show the quantity of main litter in relation to the basal area per hectare in each stand. This is an expression of the density of the stand.

The result of this comparison is presented graphically in fig. 1.

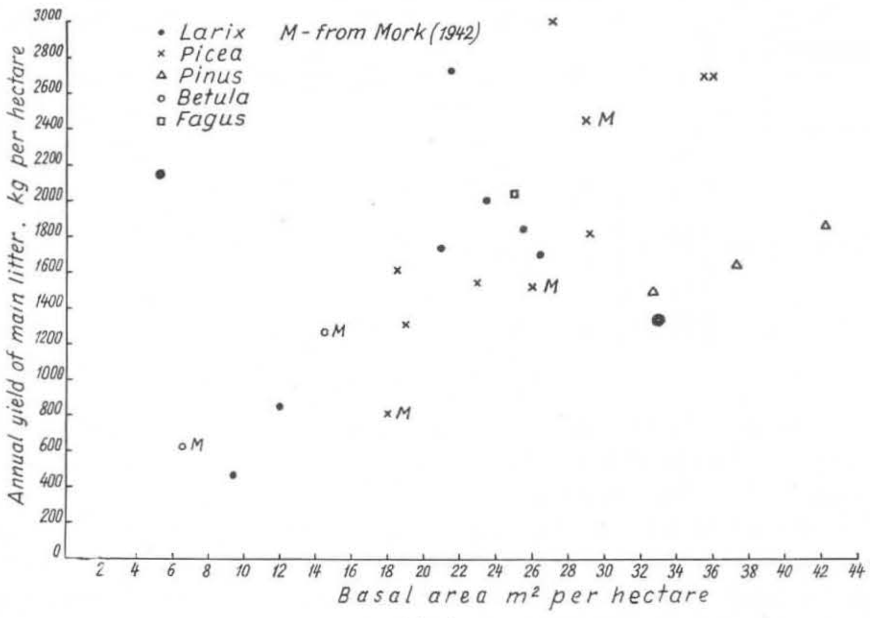


Fig. 1.

Table 3. *Yield of litter (dry matter) Kg. per hectare.*

| Plot | Year 19– | Tree species | Kind of litter | | | Sum |
|---|---|---|---|---|---|---|
| | | | Main | Residual | Other | |
| Grue .......... | 51–52 | Larix decidua | 1733± 34 | 340±154 | 37± 6 | 2110 |
| | | Picea abies | 1449± 92 | 255± 37 | 332± 39 | 2036 |
| Eidsberg ...... | 51–52 | Larix sibirica | 1901± 53 | 636±198 | 61± 9 | 2598 |
| | | Picea abies | 2396± 82 | 436± 43 | 6± 2 | 2838 |
| | 52–53 | Larix sibirica | 2103± 44 | 449± 71 | 109± 11 | 2661 |
| | | Picea abies | 2989±273 | 483±105 | 5± 2 | 3477 |
| Ringsaker | 51–52 | Larix sibirica | 1956± 66 | 733±185 | 69± 14 | 2758 |
| | | Picea abies | 1698±166 | 106± 19 | 186± 26 | 1990 |
| | 52–53 | Larix sibirica | 1727± 43 | 737±170 | 38± 9 | 2502 |
| | | Picea abies | 1667±133 | 297± 42 | 36± 10 | 2000 |
| Storelvdal .... | 51–52 | Larix sibirica | 620± 39 | 139± 34 | 210± 29 | 969 |
| | | Pinus silvestris | 1763± 45 | 746±102 | 9± 1 | 2518 |
| | 52–53 | Larix sibirica | 707± 56 | 263± 78 | 248± 30 | 1218 |
| | | Pinus silvestris | 1540± 52 | 719±102 | 34± 13 | 2293 |
| Brunlanes ...... | 51–52 | Fagus silvatica | 1572± 72 | 393± 45 | 181± 21 | 2146 |
| | | Picea abies | 2821± 93 | 933±239 | 454± 48 | 4208 |
| | 52–53 | Fagus silvatica | 2501±129 | 190± 41 | 159± 24 | 2850 |
| | | Picea abies | 2878±131 | 1304±458 | 240± 54 | 4422 |
| Ås ........... | 48–49 | Larix leptolepis | 1469± 63 | 209 | 200 | 1878 |
| | | Fagus silvatica | 2103±139 | 74 | 124 | 2301 |
| | 51–52 | Larix leptolepis | 2290±154 | 602±287 | 423±110 | 3315 |
| | | Fagus silvatica | 2805± 63 | 80± 15 | 185± 43 | 3070 |
| | 52–53 | Larix leptolepis | 3167±144 | 538±172 | 495± 89 | 4200 |
| | | Fagus silvatica | 2862±103 | 659±177 | 505± 77 | 4026 |

Some of MORK's results for Norway spruce and birch are also included here (MORK 1942). A few of our stands have been divided into groups, where the conditions were suitable for this. The litter yield and the basal area are thus calculated separately for each group within the individual stand. As might be expected, fig. 1 shows quite a large dispersion, but there is at the same time a clear tendency to an increase in the litter yield in relation to the increase in the

Table 4. *Yield of litter (dry matter). Percentage.*

| Plot | Year 19– | Tree speicies | Kind of litter: Main | Residual | Other |
|---|---|---|---|---|---|
| Grue .......... | 51–52 | Larix decidua | 82 | 16 | 2 |
| | | Picea abies | 71 | 13 | 16 |
| Eidsberg ...... | 51–52 | Larix sibirica | 73 | 25 | 2 |
| | | Picea abies | 85 | 15 | 0 |
| | 52–53 | Larix sibirica | 79 | 17 | 4 |
| | | Picea abies | 86 | 14 | 0 |
| Ringsaker ...... | 51–52 | Larix sibirica | 71 | 27 | 2 |
| | | Picea abies | 86 | 5 | 9 |
| | 52–53 | Larix sibirica | 69 | 29 | 2 |
| | | Picea abies | 83 | 15 | 2 |
| Storelvdal ...... | 51–52 | Larix sibirica | 64 | 14 | 22 |
| | | Pinus silvestris | 70 | 30 | 0 |
| | 52–53 | Larix sibirica | 58 | 22 | 20 |
| | | Pinus silvestris | 67 | 31 | 2 |
| Brunlanes ...... | 51–52 | Fagus silvatica | 73 | 18 | 9 |
| | | Picea abies | 67 | 22 | 11 |
| | 52–53 | Fagus silvatica | 87 | 7 | 6 |
| | | Picea abies | 65 | 30 | 5 |
| Ås ............ | 48–49 | Larix leptolepis | 78 | 11 | 11 |
| | | Fagus silvatica | 92 | 3 | 5 |
| | 51–52 | Larix leptolepis | 69 | 18 | 13 |
| | | Fagus silvatica | 91 | 3 | 6 |
| | 52–53 | Larix leptolepis | 75 | 12 | 13 |
| | | Fagus silvatica | 71 | 13 | 16 |

basal area. In this connection, it is interesting to notice that the figures quoted from BURGER (1945) fit in well with our material.

Our investigations appear to show that Norway spruce produces at least as much main litter as larch and beech, where the density is equal. As larch is definitely a light-demanding tree species, normal larch stands have a lower density than comparable normal stands of the tolerant species Norway spruce and beech, other conditions

being equal. A heavier fall of litter must therefore be expected in stands of Norway spruce and beech than in larch stands. Reasoning from the same basis, one can expect a lower litter yield from Scots pine than from Norway spruce.

The weights for residual litter are subject to a much larger standard error than the corresponding figures for main litter. The residual litter consists of cones, twigs, bark, etc., and the distribution of this material is much more uneven than the distribution of the main litter.

Throughout the year under investigation, the fall of residual litter in larch stands is heavier than in stands of spruce.

In Scots pine stands also there are very high figures for residual litter, and here it is especially bark and cones which are dominant. The prevalence of cones is also the reason for the high figures in the spruce stand at Brunlanes.

The figures for «Other litter» in table 3, are in reality an expression of the purity and size of the stand.

In table 4, the figures from table 3 are shown as a percentage of the total yield of litter in the stand. It is shown here that the main litter accounts for the larger part of the collected litter. Only in very few instances does this figure lie under 70 %, and there is a very clear tendency that it plays an even greater part in Norway spruce and beech stands than in larch stands.

## V. Quantity of main litter in the Aoo layer in the various stands.

MØLLER has shown that a fairly constant annual yield can probably be expected after a stand is closed (MØLLER 1945).

There is also reason to expect that the speed of decomposition and the supply of new litter will than be more or less in equilibrium (ROMELL 1932) In this way, the stock of litter will be maintained at practically the same level, and it should be possible to determine a figure for the speed of decomposition by comparing the stock with the annual fall of litter.

The collection of samples for the estimation of the main litter stock was made during the autumn of 1952, *before* the fall of litter from beech and larch.

The results can be seen in table 5, where the average yield of main

Table 5. *Rate of decomposition of „main litter".*

| *Plot* | *Tree species* | *Weight of main litter in $A_{00}$ kg/hectare* | *Annual litter fall kg/hectare* | *Years* |
|---|---|---|---|---|
| Grue ............ | Larix decidua | 2210±160 | 1733 | 1,3 |
| | Picea abies | 2490±230 | 1449 | 1,7 |
| Eidsberg .......... | Larix sibirica | 2840±520 | 2002 | 1,4 |
| | Picea abies | 7250±540 | 2693 | 2,7 |
| Ringsaker ........ | Larix sibirica | 3550±530 | 1842 | 1,9 |
| | Picea abies | 6330±2000 | 1683 | 3,8 |
| Storelvdal ........ | Larix sibirica | 2220± 340 | 664 | 3,3 |
| | Pinus silvestris | 2400± 240 | 1652 | 1,5 |
| Brunlanes ........ | Fagus silvatica | 6450± 420 | 2037 | 3,2 |
| | Picea abies | 5790±1210 | 2850 | 2,0 |
| Ås .............. | Larix leptolepis | 4920± 280 | 2309 | 2,1 |
| | Fagus silvatica | 4650± 300 | 2883 | 1,6 |

litter for the years under investigation is also shown. In addition, it is stated here how many years' yield is represented by the main litter stock. These figures have the designation «years» and form the basis for discussion of the speed of decomposition of the litter.

The figures in table 5 are very doubtful, partly because the assessment of the boundary between decomposed and undecomposed litter is a matter of individual judgment. For this reason, the results must be regarded as minimum figures. A direct comparison of the litter stock under the tree species beech and larch on the one hand, and Norway spruce and Scots pine on the other can, more over, be somewhat misleading, as the fall of litter from Norway spruce and Scots pine takes place throughout the whole year, with more or less noticeable peaks, dependent amongst other things upon the climatic conditions (Mork 1942, Viro 1955). It is therefore not at all certain that the figures shown for spruce and pine stands give the lowest value for the litter stock in the same way as for the larch and beech stands. We have, however, no material for an appraisal and possible correction of this state of affairs. The investigations show that the litter stock in the Norway spruce stands varies between 1.7 and 3.8 times the annual yield of litter. The stock under larch in the same places lies on the whole lower, between 1.3 and 1.9 times the annual yield of litter.

Larch needles decompose very slowly on poor site at Storelvdal, while pine needles decompose remarkabely quickly.

At Brunlanes, the Norway spruce needles have a comparatively high rate of decomposition, while beech leaves decompse slowly.

At Ås, beech leaves decompose relatively quickly, more so than larch needles.

The relatively slow decomposition of spruce needles on the high site classes at Eidsberg and Ringsaker is especially worthy of notice. In both of these stands, however, there is a close covering of moss, and it is possible that this hinders mechanically the spruce needles in penetrating into the decomposition zone of the humus. At Ringsaker, the moss covering occurs in patches, and this perhaps accounts for the large standard error which is found here.

*Vaccinium myrtillus* occurs more frequently at Grue and Brunlanes, and this renders the moss carpet less dense.

The fact that the litter is mechanically hindered in reaching the humus limits to a great extent the value of the method used here to estimate the speed of decomposition of the litter. The moss vegetation appears to be less dominant in stands of larch than in stands of Norway spruce, while on the other hand grass and herbs easily gain access to the light, open larch stands. Especially with a high site class will a greatly varied vegetation occur. This, again,will promote the micro-biological activity in the soil. The microclimatic conditions also must in many cases be assumed to be more favourable under larch than under Norway spruce, since the larch allows more heat and more rainfall to reach the ground. These conditions have undoubtedly an influence on the decomposition of the litter.

EBERMEYER (1876) finds in a number of plots that beech leaves decompose in the course of 3 years, Norway spruce needles 3.1 years and Scots pine needles 3.5 years. These results are not fully comparable with ours, because the investigations were made in stands where at intervals the litter was collected for agricultural purposes. The discrepancy is particularly large in the case of Scots pine. EBERMEYER mentions also, later in his work, that Scots pine needles must be expected to decompose more rapidly than Norway spruce needles, on account of the low silica content.

MIKOLA (1954) has with field experiments in Finland over the space of two years, found the following loss of organic matter: for Norway spruce 27.3 %–33.4 %, for Scots pine 57.3 %–61.6 %. The comparison between spruce and pine agrees here with our results, but the speed of decomposition is much lower.

## VI. Soil conditions and chemical composition of the main litter.

Ebermeyer (1876) has in his great work concerning ash analysis demonstrated the large variations in the mineral content of the litter from one place to another. These variations are particularly large where the calcium content of the litter is concerned.

Krauss (1926) handles exhaustively the relation between calcium and silica in fresh beech leaves, and touches also upon this relation in connection with the litter. He maintains that the amount of silica is governed by the supply of calcium in the soil. A high calcium content is conditional upon a low silica content, and vice versa. The calcium content in leaves and litter is strongly influenced by the local conditions, and in this case, not only by the calcium content of the soil, but also such circumstances as root development, humus-formation and water conditions, as well as by the climatic conditions in general.

Mork (1942) shows that the nutrient content in the litter varies from place to place, and from one year to another, and the same conditions are shown by Wittich (1953). As this coincides very well with our own results, we have therefore not found it expedient to make further enquiries regarding the outcome of other investigations. A thorough survey of literature has been made by Leiningen-Westerburg (1931), Aaltonen (1948) and Handley (1954).

Tables 6 and 7 show the chemical composition of the main litter, in the first place as a percentage of dry matter and in the second as a percentage of ash. The results in table 6 are also shown graphically in figures 2, 3 and 4.

For each plot and each year an attempt has been made to establish whether the difference in chemical composition found between the various tree species is significant.

The material from each stand is segregated in 4—5 groups, according to the position of the pots. In this way, 6—8 degrees of freedom are obtained within each area for the determining of significance (Ås 1952—53 has only 4 degrees of freedom). Since the material for observation is limited, we have availed ourselves of Student's t-test, in order to confirm possible significance. After each analysis number in the table there is given the standard error of the mean. In the column marked «Diff.» there is given the difference of the mean figures. Values which are significantly different from zero are indicated by stars (* $< 5\%$, ** $< 1\%$ and *** $< 0{,}1\%$).

Table 6. *Chemical composition of main litter.*

| *Plot* | *Year* 19– | *Tree species* | *Percentage of dry matter* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ca | Mg | Mn | K | P | N | Si | Ash |
| Grue | 51–52 | Larix decidua | 0.722±0.034 | 0.153±0.007 | 0.254±0.028 | 0.117±0.005 | 0.092±0.004 | 0.708±0.022 | 0.986±0.040 | 4.47±0.08 |
| | | Picea abies | 1.163±0.050 | 0.091±0.006 | 0.230±0.013 | 0.167±0.001 | 0.102±0.003 | 0.820±0.020 | 0.957±0.038 | 5.94±0.21 |
| | | Diff. | ÷0.441*** | 0.062*** | 0.024 | ÷0.050*** | ÷0.010 | ÷0.112* | 0.029 | ÷1.47*** |
| | 52–53 | Larix decidua | 0.570±0.023 | 0.121±0.008 | 0.228±0.010 | 0.112±0.005 | 0.089±0.001 | 0.663±0.029 | 1.116±0.050 | 5.04±0.01 |
| | | Picea abies | 1.150±0.030 | 0.092±0.008 | 0.228±0.012 | 0.163±0.016 | 0.093±0.003 | 0.832±0.018 | 0.970±0.034 | 5.86±0.17 |
| | | Diff. | ÷0.580*** | 0.029 | 0.000 | ÷0.051* | ÷0.004 | ÷0.169** | 0.146 | ÷0.82*** |
| Eidsberg | 51–52 | Larix sibirica | 0.763±0.035 | 0.229±0.007 | 0.045±0.002 | 0.174±0.007 | 0.100±0.013 | 1.280±0.023 | 1.376±0.056 | 5.73±0.16 |
| | | Picea abies | 0.926±0.048 | 0.111±0.003 | 0.099±0.003 | 0.212±0.004 | 0.109±0.004 | 1.125±0.010 | 1.085±0.043 | 5.13±0.08 |
| | | Diff. | ÷0.163* | 0.118*** | ÷0.054*** | ÷0.038** | ÷0.009 | 0.155*** | 0.291** | 0.60* |
| | 52–53 | Larix sibirica | 0.589±0.020 | 0.175±0.003 | 0.047±0.002 | 0.171±0.008 | 0.116±0.003 | 1.401±0.027 | 1.495±0.035 | 6.78±0.16 |
| | | Picea abies | 0.842±0.016 | 0.095±0.003 | 0.091±0.008 | 0.133±0.006 | 0.101±0.003 | 1.162±0.017 | 0.978±0.024 | 5.15±0.08 |
| | | Diff. | ÷0.253*** | 0.080*** | ÷0.044*** | 0.038** | 0.015** | 0.239*** | 0.517*** | 1.63*** |
| Ringsaker | 51–52 | Larix sibirica | 0.639±0.015 | 0.237±0.006 | 0.082±0.007 | 0.169±0.006 | 0.089±0.003 | 0.740±0.020 | 0.980±0.018 | 4.65±0.07 |
| | | Picea abies | 1.247±0.034 | 0.101±0.005 | 0.119±0.012 | 0.157±0.006 | 0.104±0.002 | 0.940±0.018 | 1.000±0.036 | 6.00±0.02 |
| | | Diff. | ÷0.608*** | 0.136*** | ÷0.037* | 0.012 | ÷0.015*** | ÷0.200*** | ÷0.020 | ÷1.35*** |
| | 52–53 | Larix sibirica | 0.550±0.018 | 0.137±0.004 | 0.069±0.003 | 0.102±0.003 | 0.100±0.004 | 1.107±0.041 | 1.086±0.021 | 4.69±0.09 |
| | | Picea abies | 1.298±0.052 | 0.083±0.002 | 0.135±0.004 | 0.148±0.009 | 0.104±0.003 | 0.992±0.019 | 1.077±0.123 | 5.78±0.10 |
| | | Diff. | ÷0.748*** | 0.054*** | ÷0.066*** | ÷0.046*** | ÷0.004 | 0.115* | 0.009 | ÷1.09*** |

Table 6 continued

| *Plot* | *Year* 19– | *Tree species* | *Percentage of dry matter* Ca | Mg | Mn | K | P | N | Si | Ash |
|---|---|---|---|---|---|---|---|---|---|---|
| Storelvdal | 51–52 | Larix sibirica | 0.428±0.031 | 0.165±0.007 | 0.128±0.026 | 0.112±0.011 | 0.094±0.006 | 0.485±0.013 | 0.854±0.020 | 3.72±0.14 |
| | | Pinus silvestris | 0.496±0.050 | 0.064±0.003 | 0.131±0.020 | 0.073±0.004 | 0.034±0.001 | 0.472±0.005 | 0.113±0.022 | 1.92±0.14 |
| | | Diff. | ÷0.068 | 0.101*** | ÷0.003 | 0.039* | 0.060*** | 0.013 | 0.741*** | 1.80*** |
| | 52–53 | Larix sibirica | 0.443±0.032 | 0.152±0.007 | 0.137±0.026 | 0.120±0.008 | 0.114±0.002 | 0.570±0.008 | 0.928±0.042 | 4.15±0.21 |
| | | Pinus silvestris | 0.459±0.036 | 0.050±0.003 | 0.111±0.021 | 0.054±0.002 | 0.034±0.001 | 0.566±0.030 | 0.094±0.007 | 1.63±0.17 |
| | | Diff. | ÷0.016 | 0.102*** | 0.026 | 0.066*** | 0.080*** | 0.004 | 0.834*** | 2.52*** |
| Brunlanes | 51–52 | Fagus silvatica | 1.184±0.022 | 0.133±0.002 | 0.181±0.016 | 0.136±0.002 | 0.070±0.002 | 1.020±0.020 | 1.058±0.075 | 5.79±0.19 |
| | | Picea abies | 0.913±0.076 | 0.095±0.001 | 0.172±0.013 | 0.189±0.009 | 0.099±0.004 | 1.100±0.014 | 0.978±0.054 | 5.09±0.24 |
| | | Diff. | 0.271** | 0.038*** | 0.009 | ÷0.053*** | ÷0.029*** | ÷0.080* | 0.080 | 0.70 |
| | 52–53 | Fagus silvatica | 1.038±0.008 | 0.112±0.003 | 0.228±0.017 | 0.092±0.004 | 0.081±0.001 | 0.968±0.018 | 0.913±0.027 | 5.71±0.07 |
| | | Picea abies | 0.976±0.054 | 0.082±0.003 | 0.196±0.011 | 0.158±0.010 | 0.096±0.006 | 1.047±0.015 | 1.010±0.034 | 5.70±0.18 |
| | | Diff. | 0.062 | 0.030*** | 0.032 | ÷0.066*** | ÷0.015* | ÷0.079* | ÷0.097 | 0.01 |
| Ås | 48–49 | Larix leptolepis | 0.452±0.016 | | | 0.093±0.008 | 0.051±0.004 | 0.890±0.041 | 1.198±0.029 | 4.12±0.10 |
| | | Fagus silvatica | 1.220±0.050 | | | 0.314±0.013 | 0.073±0.003 | 1.070±0.058 | 1.470±0.041 | 6.89±0.10 |
| | | Diff. | ÷0.768*** | | | ÷0.221*** | ÷0.023** | ÷0.180 | ÷0.272*** | ÷2.77*** |
| | 51–52 | Larix leptolepis | 0.588±0.017 | 0.139±0.003 | 0.037±0.008 | 0.112±0.007 | 0.037±0.002 | 0.753±0.016 | 1.063±0.017 | 3.90±0.05 |
| | | Fagus silvatica | 1.318±0.061 | 0.197±0.007 | 0.115±0.010 | 0.368±0.029 | 0.077±0.005 | 1.270±0.049 | 1.253±0.005 | 6.90±0.08 |
| | | Diff. | ÷0.730*** | ÷0.058*** | ÷0.078*** | ÷0.256*** | ÷0.040*** | ÷0.517*** | ÷0.190*** | ÷3.00*** |
| | 52–53 | Larix leptolepis | 0.422±0.030 | 0.068±0.002 | 0.043±0.003 | 0.056±0.002 | 0.040±0.001 | 0.899±0.029 | 0.974±0.024 | 3.57±0.04 |
| | | Fagus silvatica | 1.205±0.013 | 0.135±0.003 | 0.125±0.005 | 0.124±0.012 | 0.071±0.006 | 1.372±0.001 | 1.192±0.049 | 6.28±0.20 |
| | | Diff. | ÷0.783*** | ÷0.067*** | ÷0.082*** | ÷0.068* | ÷0.031* | ÷0.473*** | ÷0.218* | ÷2.71*** |

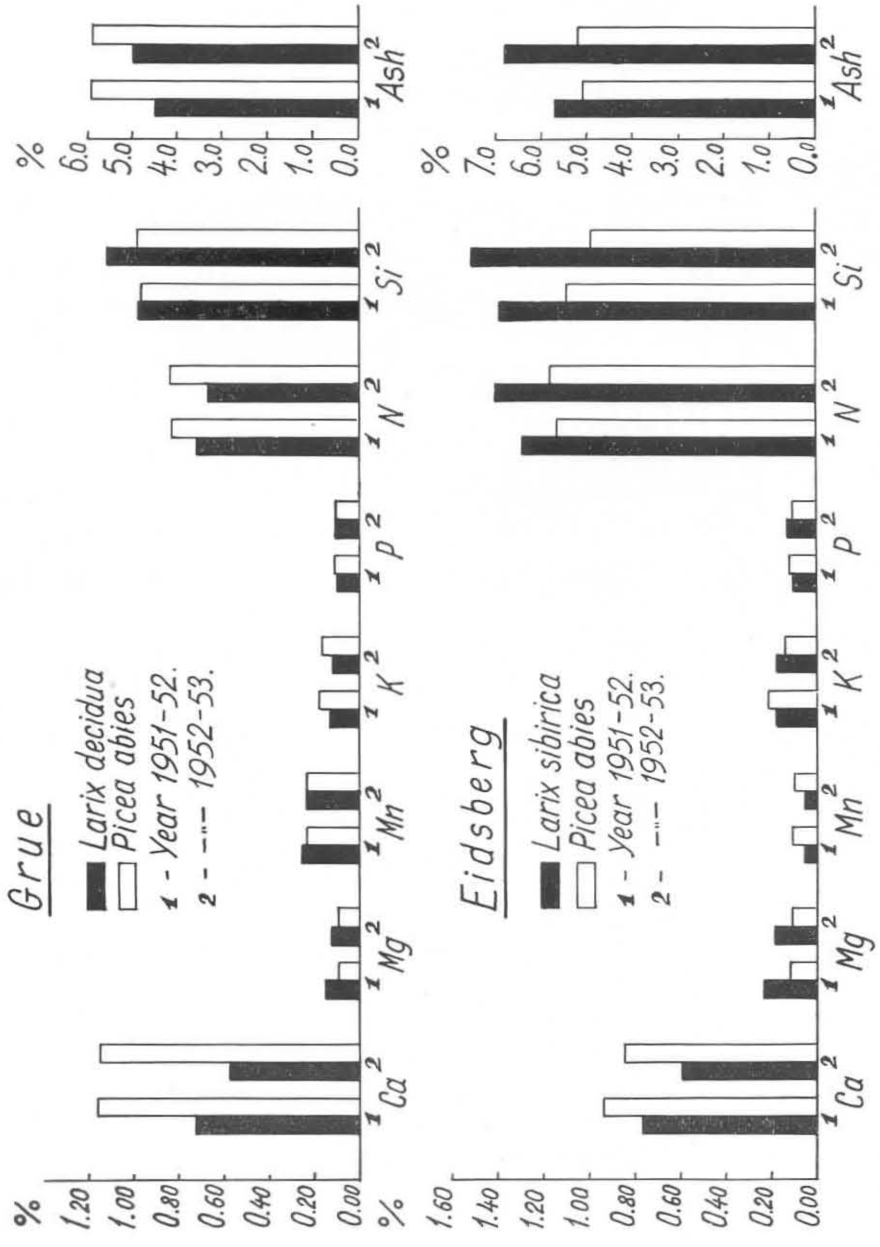


Fig. 2. Chemical composition of main litter. Percentage of dry matter.

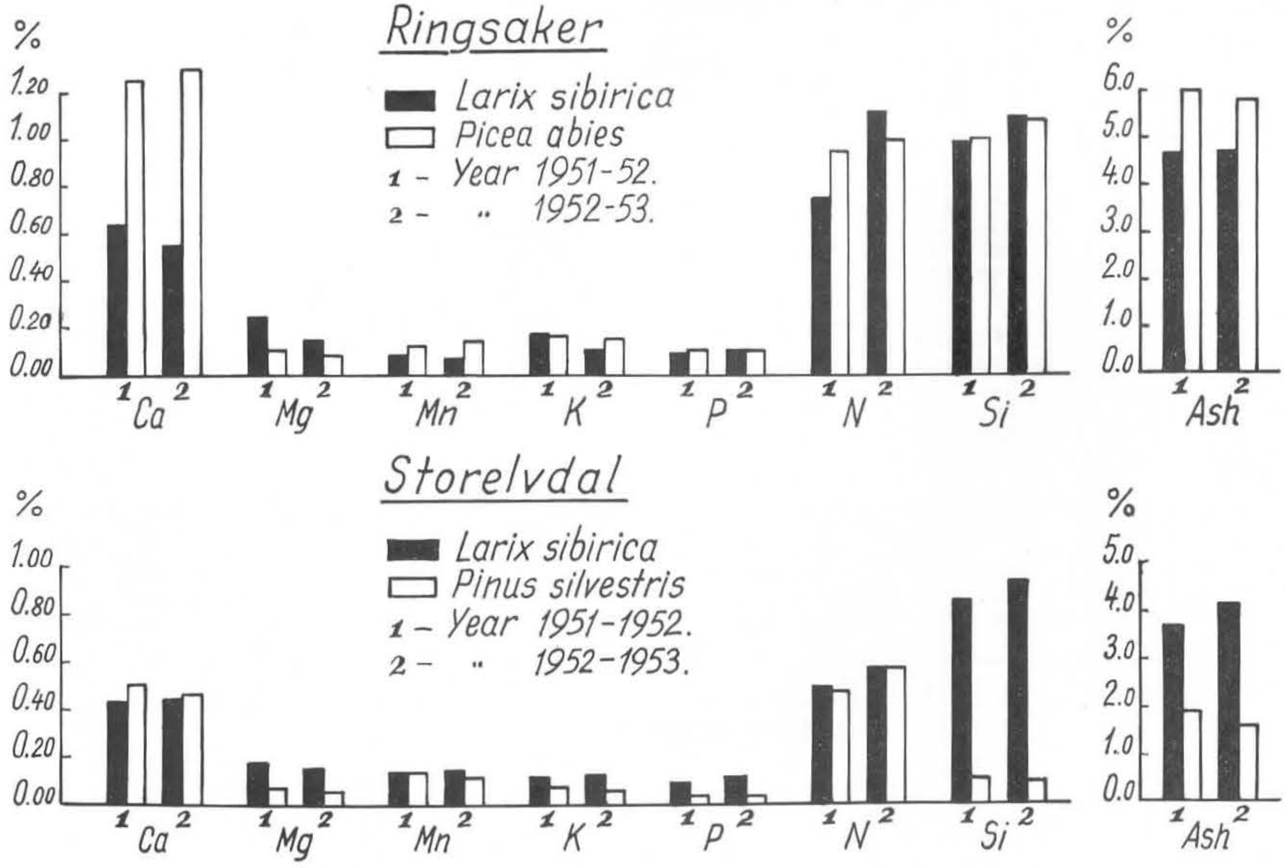


Fig. 3. Chemical composition of main litter. Percentage of dry matter.

Table 7. *Chemical composition of main litter.*

| *Plot* | *Year* 19– | *Tree species* | *Percentage of ash* | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Ca | Mg | Mn | K | P | Si |
| Grue | 51–52 | Larix decidua | 16.15±0.75 | 3.42±0.08 | 5.70±0.63 | 2.41±0.18 | 2.06±0.09 | 22.02±0.65 |
| | | Picea abies | 19.56±0.19 | 1.53±0.04 | 3.86±0.14 | 2.81±0.11 | 1.72±0.10 | 16.10±0.16 |
| | | Diff. | ÷3.41* | 1.89*** | 1.84 | ÷0.40 | 0.34* | 5.92*** |
| | 52–53 | Larix decidua | 11.29±0.58 | 2.40±0.21 | 4.51±0.25 | 1.98±0.27 | 1.75±0.01 | 22.14±1.01 |
| | | Picea abies | 19.65±0.44 | 1.57±0.13 | 3.89±0.10 | 2.79±0.31 | 1.59±0.08 | 16.56±0.13 |
| | | Diff. | ÷8.36*** | 0.83* | 0.62 | ÷0.81 | 0.16 | 5.58** |
| Eidsberg | 51–52 | Larix sibirica | 13.29±0.33 | 4.02±0.20 | 0.79±0.06 | 3.04±0.08 | 1.73±0.12 | 24.00±0.62 |
| | | Picea abies | 18.07±0.40 | 2.17±0.02 | 1.94±0.07 | 4.14±0.16 | 2.14±0.07 | 21.15±0.62 |
| | | Diff. | ÷4.78*** | 1.85*** | ÷1.15*** | ÷1.10*** | ÷0.41* | 2.85* |
| | 52–53 | Larix sibirica | 8.67±0.20 | 2.59±0.06 | 0.69±0.04 | 2.52±0.14 | 1.71±0.05 | 22.05±0.47 |
| | | Picea abies | 16.36±0.33 | 1.84±0.07 | 1.77±0.16 | 2.58±0.13 | 1.96±0.08 | 18.99±0.36 |
| | | Diff. | ÷7.69*** | 0.75*** | ÷1.09*** | ÷0.06 | ÷0.25* | 3.06** |
| Ringsaker | 51–52 | Larix sibirica | 13.77±0.01 | 5.11±0.09 | 1.76±0.15 | 3.66±0.01 | 1.92±0.07 | 21.10±0.17 |
| | | Picea abies | 20.80±0.66 | 1.68±0.08 | 1.99±0.19 | 2.63±0.06 | 1.74±0.00 | 16.65±0.53 |
| | | Diff. | ÷7.03*** | 3.43*** | ÷0.23 | 1.03*** | 0.18* | 4.45*** |
| | 52–53 | Larix sibirica | 11.73±0.26 | 2.92±0.13 | 1.48±0.08 | 2.19±0.09 | 2.15±0.13 | 23.16±0.18 |
| | | Picea abies | 22.48±0.86 | 1.44±0.07 | 2.34±0.08 | 2.57±0.17 | 1.80±0.06 | 18.65±0.46 |
| | | Diff. | ÷10.75*** | 1.48*** | ÷0.86*** | ÷0.38 | 0.35* | 4.51*** |

Table 7 continued.

| Plot | Year 19– | Tree species | Percentage of ash | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Ca | Mg | Mn | K | P | Si |
| Storelvdal | 51–52 | Larix sibirica | 11.44±0.45 | 4.48±0.30 | 3.36±0.59 | 3.07±0.40 | 2.55±0.13 | 23.04±0.49 |
| | | Pinus silvestris | 25.68±0.75 | 3.40±0.30 | 6.67±0.77 | 3.91±0.39 | 1.79±0.15 | 5.54±0.63 |
| | | Diff. | ÷14.24*** | 1.08* | ÷3.31** | ÷0.84 | 0.76** | 17.50*** |
| | 52–53 | Larix sibirica | 10.62±0.26 | 3.72±0.32 | 3.21±0.48 | 2.96±0.29 | 2.79±0.17 | 22.39±0.27 |
| | | Pinus silvestris | 29.02±2.96 | 3.22±0.41 | 6.93±1.39 | 3.46±0.36 | 2.18±0.26 | 6.05±0.90 |
| | | Diff. | ÷18.40*** | 0.50 | ÷3.72* | ÷0.50 | 0.61 | 16.34*** |
| Brunlanes | 51–52 | Fagus silvatica | 20.49±0.62 | 2.30±0.63 | 3.13±0.26 | 2.34±0.06 | 1.21±0.03 | 18.20±0.73 |
| | | Picea abies | 17.86±0.95 | 1.89±0.11 | 3.42±0.38 | 3.73±0.21 | 1.95±0.09 | 19.20±0.51 |
| | | Diff. | 2.63* | 0.41* | ÷0.29 | ÷1.39** | ÷0.74*** | ÷1.00 |
| | 52–53 | Fagus silvatica | 18.20±0.34 | 1.97±0.07 | 4.00±0.31 | 1.61±0.07 | 1.42±0.02 | 16.00±0.43 |
| | | Picea abies | 17.10±0.92 | 1.44±0.04 | 3.46±0.26 | 2.77±0.17 | 1.69±0.12 | 17.76±0.65 |
| | | Diff. | 1.10 | 0.53*** | 0.54 | ÷1.16*** | ÷0.27* | ÷1.76* |
| Ås | 48–49 | Larix leptolepis | 10.98±0.11 | | | 2.21±0.17 | 1.23±0.12 | 29.08±0.68 |
| | | Fagus silvatica | 17.75±0.12 | | | 4.59±0.09 | 1.07±0.04 | 21.33±0.41 |
| | | Diff. | ÷6.77*** | | | ÷2.38*** | 0.16 | 7.75*** |
| | 51–52 | Larix leptolepis | 15.03±0.63 | 3.58±0.12 | 0.95±0.22 | 2.88±0.20 | 0.95±0.03 | 27.43±0.45 |
| | | Fagus silvatica | 18.80±0.78 | 2.85±0.12 | 1.66±0.14 | 5.35±0.46 | 1.11±0.06 | 18.13±0.56 |
| | | Diff. | ÷3.77* | 0.73** | ÷0.71* | ÷2.47** | ÷0.16 | 9.30*** |
| | 52–53 | Larix leptolepis | 11.82±0.96 | 1.91±0.08 | 1.21±0.10 | 1.56±0.06 | 1.11±0.02 | 27.27±0.38 |
| | | Fagus silvatica | 19.25±0.47 | 2.15±0.09 | 1.99±0.03 | 1.98±0.14 | 1.13±0.06 | 19.00±0.49 |
| | | Diff. | ÷7.43** | ÷0.25 | ÷0.79*** | ÷0.42 | ÷0.02 | 8.27*** |

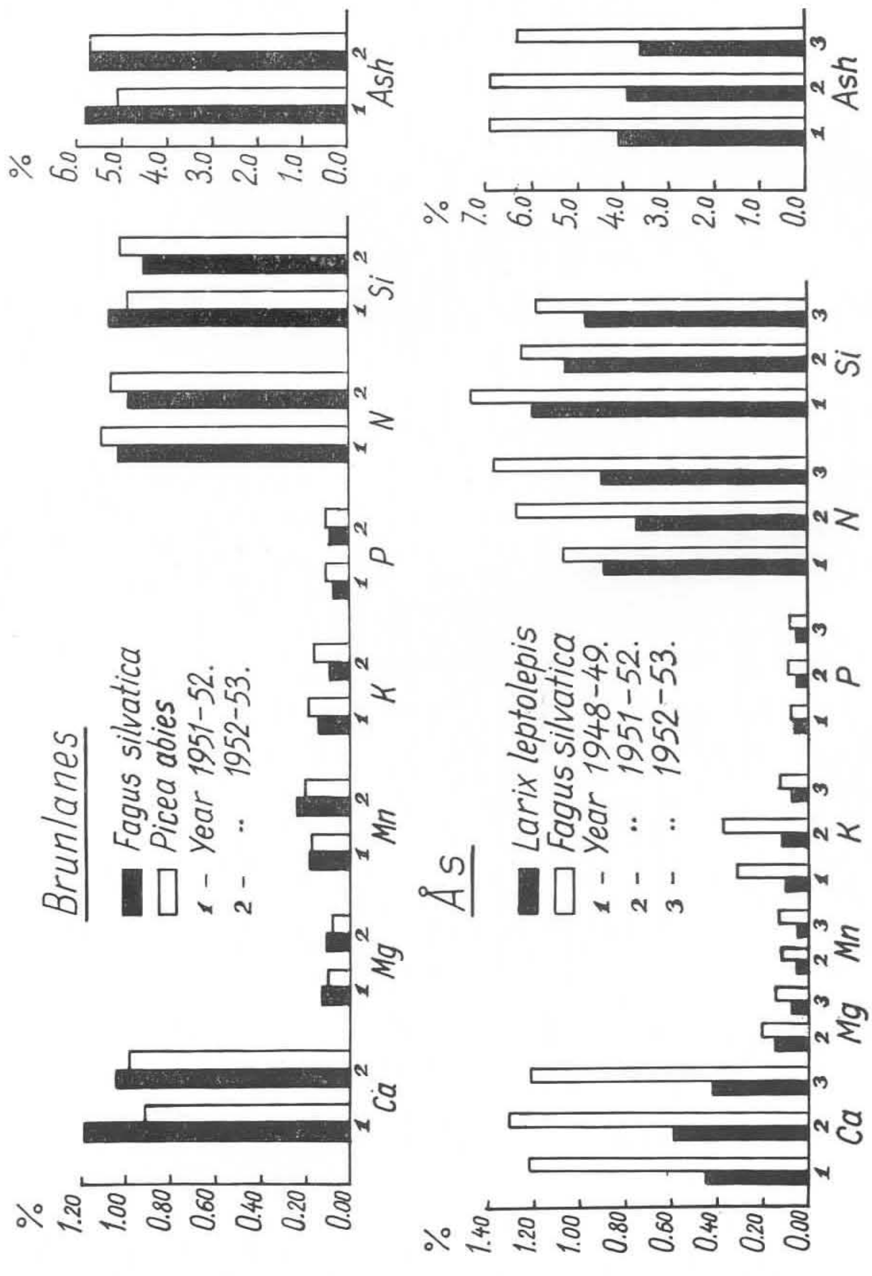


Fig. 4. Chemical composition of main litter. Percentage of dry matter.

As previously indicated, the main litter comprises the major part of the total yield of forest litter, and it is therefore natural to consider this in relation to the soil conditions.

The soil conditions are presented by means of three tables. Table 8 gives a chemical description of the soil profiles in the stands investigated. In the table, the standard error of the mean is calculated where there are at least three analyses for the same layer. Table 9 shows the mechanical composition of the subsoil.

Table 10 gives the analyses of the humus layer. For each plot is given the difference between the mean figures in the two stands. Here also Student's t-test was employed.

1. *The plots at Grue, Eidsberg and Ringsaker. Comparison between larch and Norway spruce.*

a. Soil.

At Grue and Ringsaker, the subsoil consists of slightly clayey to clayey, coarse fine sand. There is here little or no difference between the Norway spruce and larch stand. At Eidsberg, the subsoil in the larch plot consists of sandy clay, and in the spruce plot of clayey very fine sand. The larch stand must therefore be assumed to be situated on somewhat better soil than the spruce stand.

pH increases, on the whole, towards the base of the profile.

The pH for the subsoil shows little variation – from pH 5,30 at Grue to 5,67 at Eidsberg.

The percentages for loss on ignition show a marked decrease lower in the profiles, especially at Grue, where we have raw humus, but somewhat lower at Eidsberg and Ringsaker, where we have mull.

The M- and L-figures and the amount of ammoniumchloride-soluble potassium follows the percentage for loss on ignition. These figures are very low for the subsoil, so that the difference between the individual stands and plots is small. The standard error of the mean figures is often very considerable, and no firm tendency can be traced.

The quantity of ammoniumchloride-soluble calcium also shows a close connection with the quantity of organic matter. The calcium content in the subsoil from Eidsberg is the highest, and that from Ringsaker the lowest. There is a certain discrepancy between the mean figures from spruce and larch stands at Eidsberg, but by reason of the large standard error the difference is not significant.

The quantity of inorganic phosphorus lies in several cases higher

Table 8. *Chemical description of the soil profiles.*

| Plot | Tree species | Layer | Thickness in cm. | pH | Loss on ignition in per cent of dry matter | M-figure | L-figure | mg. per 100 grm. dry matter: $NH_4Cl$-soluble K | mg. per 100 grm. dry matter: $NH_4Cl$-soluble Ca | mg. per 100 grm. dry matter: Inorganic P |
|---|---|---|---|---|---|---|---|---|---|---|
| Grue ...... | Larix decidua | $A_0$ | 2.8±0.25 | 4.23±0.20 | 85.1±1.64 | 69.7±6.68 | 27.3±0.39 | | 289 | 11.4±0.61 |
| | | $A_2$ | 12.8±3.6 | 4.13±0.05 | 1.0 | 3.33±0.48 | 1.25±0.31 | 2.35±0.24 | | |
| | | $B_2$ | 25 | 4.98±0.19 | 1.9 | 2.84±0.20 | 0.43±0.33 | 1.84±0.19 | | |
| | | C | | 5.3 | 2.9 | 2.2 | 0.1 | 1.8 | 7.2 | 13.1 |
| | Picea abies ...... | $A_0$ | 3.8±0.37 | 4.18±0.05 | 85.9±2.43 | 133.3±11.1 | 37.8±3.77 | | 439 | 13.1±5.68 |
| | | $A_2$ | 15.4±2.5 | 4.30±0.20 | 2.1 | 3.00±0.37 | 0.90±0.33 | 1.98±0.41 | | |
| | | $B_2$ | 14 | 5.07±0.18 | 5.9 | 3.20±0.81 | 0.17±0.12 | 2.53±0.63 | | |
| | | B–C | | 5.3 | 3.5 | 2.9 | 0.2 | 2.7 | 10.3 | 6.1 |
| Eidsberg .. | Larix sibirica .... | $A_{11}$ | 5.8±0.37 | 4.86±0.04 | 10.5±1.03 | 9.90±1.05 | 3.00±0.56 | | 98 | 23.6±2.21 |
| | | $A_{12}$ | 18.3±1.7 | 5.17±0.14 | 6.0 | 5.21±0.92 | 1.13±0.04 | 7.23±1.34 | 27.7±10.1 | |
| | | (B) | 12 | 5.33±0.13 | 3.1 | 3.63±0.58 | 0.77±0.86 | 5.26±1.24 | 13.1±1.93 | |
| | | (B)–C | | 5.47±0.08 | 2.5 | 3.07±0.69 | 0.53±0.04 | 4.40±1.06 | 14.7±1.48 | 27.0±2.86 |
| | Picea abies ...... | $A_{11}$ | 2.3±1.1 | 4.40±0.10 | 25.1±1.00 | 15.3±0.80 | 4.87±1.04 | | 323 | 13.8±0.64 |
| | | $A_{12}$ | 20.0±2.9 | 4.73±0.09 | 9.7 | 6.03±0.82 | 0.67±0.04 | 8.70±0.54 | 12.9±2.84 | |
| | | (B) | 22 | 5,3 | 2,1 | 2,0 | 0.2 | 2,1 | 3,4 | |
| | | (B)–C | | 5.67±0.12 | 1.9 | 2.73±0.96 | 0.50±0.15 | 3.40±0.32 | 29.6±18.5 | 44.3±6.5 |
| Ringsaker .. | Larix sibirica .... | $A_{11}$ | 2.8±1.1 | 4.52±0.35 | 13.7±0.65 | 11.6±1.00 | 7.32±0.45 | | 129 | 8.72±1.18 |
| | | $A_{12}$ | 8.8±0.85 | 4.5 | | 4.3 | 1.7 | 3.0 | | |
| | | (B) | 32 | 4.86±0.10 | 2.90±1.03 | 1.96±0.41 | 0.28±0.02 | 2.38±0.44 | | |
| | | C | | 5.62±0.05 | 1.70±0.37 | 1.88±0.34 | 0.70±0.17 | 1.94±0.34 | 4.1 | 48.5±11.4 |
| | Picea abies ...... | $A_{11}$ | 2.2±0.20 | 4.34±0.14 | 13.1±0.80 | 12.7±3.59 | 4.56±1.51 | | 79 | 9.96±0.70 |
| | | $A_{12}$ | 8.6±1.1 | 4.3 | 8.2 | 3.4 | 0.9 | 2.9 | | |
| | | (B) | 29 | 5.02±0.10 | 3.13±0.51 | 1.48±0.65 | 0.20±0.06 | 2.14±0.63 | | |
| | | (B)–C | | 5.58±0.08 | 1.90±0.39 | 0.90±0.10 | 0.28±0.07 | 2.08±0.16 | 5,2 | 63.7±8.46 |

Table 8 continued

| Plot | Tree species | Layer | Thickness in cm. | pH | Loss on ignition in per cent of dry matter | M-figure | L-figure | mg. per 100grm. dry matter: $NH_4Cl$-soluble K | $NH_4Cl$-soluble Ca | Inorganic P |
|---|---|---|---|---|---|---|---|---|---|---|
| Storelvdal . . | Larix sibirica . . . . | $A_0$ | 2.6±0.40 | 3.90±0.08 | 76.4±3.42 | 65 | 21.7±1.45 | | 227 | 12.8±1.86 |
| | | $A_2$ | 9.2±1.3 | 4.33±0.02 | 0.8 | 3.45±1.75 | 1.28±0.35 | 2.85±1.65 | | |
| | | $B_2$ | 18 | 5.70±0.34 | 2.8 | 1.90±0.12 | 0.68±0.13 | 1.35±0.22 | | |
| | | C | | 6.06±0.10 | 0.4 | 1.06±0.33 | 1.12±0.17 | 0.90±0.36 | 11.4 | 17.6±2.27 |
| | Pinus silvestris . . . . | $A_0$ | 4.0±0.57 | 3.58±0.06 | 88.7±1.48 | 96.0±9.16 | 22.7±2.40 | | 328 | 15.4±2.78 |
| | | $A_2$ | 9.0±1.6 | 4.08±0.04 | 1.6 | 2.68±0.20 | 0.88±0.11 | 1.86±0.21 | | |
| | | $B_2$ | 15 | 5.50±0.09 | 2.3 | 2.44±0.16 | 1.20±0.89 | 1.80±0.16 | | |
| | | C | | 5.80±0.07 | 0.5 | 1.60±0.33 | 1.12±0.18 | 0.96±0.12 | 7.2 | 17.1±4.92 |
| Brunlanes . . | Fagus silvatica . . . . | $A_0$ | 7.8±1.0 | 3.90±0.39 | 79.7±5.62 | 96.2±9.89 | 14.0±3.73 | | 284 | 7.68±0.7 |
| | | $A_1$ | 11.3±0.48 | 4.45±0.23 | 10.2 | 9.03±1.14 | 1.45±0.45 | 8.15±1.34 | | |
| | | $B_{20}$ | | 4.70±0.12 | 15.2 | 6.85±1.76 | 0.38±0.24 | 6.25±2.89 | | |
| | | $B_{21}$ | | 4.83±0.17 | 5.7 | 5.60±1.10 | 0.05±0.05 | 4.60±1.46 | 14.5 | 67.3±43.3 |
| | Picea abies . . . . . . | $A_0$ | 7.3±0.63 | 4.23±0.14 | 71.4±7.30 | 82.0±11.4 | 20.8±3.64 | | 339 | 11.7±1.30 |
| | | $A_1$ | 6.7±2.8 | 4.23±0.11 | 14.6 | 11.3±1.79 | 2.45±1.25 | 11.0±0.98 | | |
| | | $B_{20}$ | | 4.85±0.06 | 10.7 | 6.60±0.69 | 0.15±0.09 | 5.05±1.35 | | |
| | | $B_{21}$ | | 5.12±0.12 | 10.1 | 3.73±0.63 | 0.05±0.05 | 3.70±0.76 | 3.5 | 74.2±7.90 |
| Ås . . . . . . . . | Larix leptolepis . . . | $A_{11}$ | 4 | 4.37±0.08 | 23.9±0.18 | 26.4±0.58 | 2.55±0.70 | | 86.3±16.3 | 11.1±1.69 |
| | | $A_{12}$ | 10 | 4.28±0.13 | 12.8±1.50 | 8.90±1.08 | 0.88±0.12 | | 30.5±7.18 | |
| | | $A_{13}$ | 19 | 4.30±0.08 | 6.78±0.63 | 4.1 | 0.4 | | 11.9 | |
| | | (B) | 16 | 4.84±0.03 | 2.8 | 3.0 | 0.3 | | 11.8 | |
| | | C | | 5.3 | 2.9 | 3.6 | 0.2 | | 11.7 | |
| | Fagus silvatica . . . . | $A_{11}$ | 5.7±1.85 | 4.94±0.05 | 16.3±0.10 | 22.1±0.49 | 1.23±0.16 | | 80.0±5.36 | 16.3±1.45 |
| | | $A_{12}$ | 13.3±1.67 | 4.58±0.47 | 8.35±0.21 | 8.05±3.48 | 0.65±0.09 | | 33.8±10.2 | |
| | | (B) | 19 | 4.68±0.14 | 4.30±0.43 | 3.6 | 0.33±0.92 | | 66.6 | |
| | | C | | 5.08±0.33 | 2.10±0.36 | 4.2 | 0.1 | | 141 | |

Table 9. *Mechanical composition of the fine earth (< 2 mm). Subsoil.*

| *Plot* | *Tree species* | *Percentage of material < 2 mm* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2–0.6 mm | 0.6–0.2 mm | 0.2–0.06 mm | 0.06–0.02 mm | 0.02–0.006 mm | 0.006–0.002 mm | <0.002 mm |
| Grue ........ | Larix decidua | 8.8 | 20.6 | 30.8 | 20.1 | 11.2 | 3.6 | 4.9 |
| | Picea abies | 6.7 | 18.1 | 29.3 | 23.6 | 12.3 | 3.8 | 6.2 |
| Eidsberg .... | Larix sibirica | 9.4 | 20.4 | 3.3 | 5.9 | 17.8 | 17.2 | 26.0 |
| | Picea abies | 0.9 | 2.6 | 18.7 | 42.2 | 14.5 | 6.4 | 14.7 |
| Ringsaker .... | Larix sibirica | 13.5 | 23.8 | 32.6 | 10.8 | 9.4 | 3.8 | 6.1 |
| | Picea abies | 8.4 | 19.9 | 39.9 | 15.8 | 7.8 | 3.2 | 5.0 |
| Storelvdal .... | Larix sibirica | 18.4 | 41.3 | 16.7 | 11.1 | 7.1 | 4.3 | 1.1 |
| | Pinus silvestris | 13.8 | 28.4 | 23.0 | 19.9 | 10.8 | 1.4 | 2.7 |
| Brunlanes .... | Fagus silvatica | 26.4 | 30.0 | 9.0 | 8.0 | 4.5 | 3.2 | 13.9 |
| | Picea abies | 44.0 | 19.9 | 10.7 | 10.5 | 5.1 | 2.7 | 7.1 |
| Ås .......... | Larix leptolepis | 34.6 | | 26.5 | | 28.9 | | 10.0 |
| | Fagus silvatica | 23.5 | | 34.0 | | 32.6 | | 9.9 |

in the subsoil than in the humus layer. Here there is a considerable difference between the subsoil in the three plots. The phosphorus content increases in the following sequence: Grue–Eidsberg–Ringsaker. At Eidsberg, the subsoil in the spruce stand is richer in phosphorus than in the larch stand. The difference is, however, not significant.

b. Litter.

*Calcium.* On every plot there is a distinct difference in the calcium content of larch and Norway spruce needles. The larch needles are poorer in calcium, both when this is calculated as a percentage of dry matter and as a percentage of ash.

The variations in calcium content from plot to plot are quite large, especially for spruce needles. The larch needles show also a great variation from one year to another. No connection has been found between the content of calcium in the litter and the content of easily-soluble calcium in the soil, neither between calcium content and site class.

*Magnesium.* Larch needles are richer in magnesium than Norway spruce needles. The difference is significant, with the exception of Grue 1952–53. The ash from the larch needles also is richer in magne-

sium than the ash from spruce needles. The magnesium content in spruce needles is fairly constant from plot to plot, while the larch needles show a somewhat larger variation, both between plots and from one year to another.

*Manganese.* With the exception of Grue, where the manganese content is very high both in larch and spruce, the needles of the latter are richer in manganese than larch needles. The same conditions apply to the ash.

Investigations by SCHÜTZE (1876) show that Scots pine which grows in poor soil has a high manganese content in the ash. This should indicate a deficiency of chalk, and difficulty in assimilating calcium (COUNCLER 1883, 1903). The solubility of manganese in the soil is greatly dependent upon the conditions of oxidation and on the acidity. With a low pH, a plant will asimilate more manganese than with a high pH.

There is in our material a certain connection between manganese content in the litter and pH in the upper layers of the soil.

*Potassium.* The Norway spruce needles from Grue are richer in potassium than the larch needles. For the other plots, the conditions vary from plot to plot, and from one year to another.

No connection is found between the potassium content in the litter and the content of easily soluble potassium in the soil.

*Phosphorus.* The content of phosphorus shows little variation within the scope of our material, and no difference between larch and Norway spruce can be indicated.

The ash of the larch needles is richer in phosphorus at Ringsaker, and this is also the case at Grue 1951–52, while the opposite applies at Eidsberg.

*Nitrogen.* The larch needles at Grue are poorer in nitrogen than the corresponding Norway spruce needles, while at Eidsberg the opposite applies. At Ringsaker, the nitrogen content rises so much in larch needles from one year to the next that while in 1951–52 there is a definite negative difference between larch and spruce, the opposite applies in 1952–53, although admittedly with weaker significance.

There is a very slight tendency to a connection between the nitrogen content in the needles and in the humus. The nitrogen content in the humus rises in the following order: Grue–Ringsaker–Eidsberg, as also does the nitrogen content in the needles both for larch and for spruce. It is, however, not possible here to differentiate between cause and effect.

Table 10. *Chemical analyses*

| *Plot* | *Tree species* | *Thickness in cm* | *pH* | *Organic matter in per cent of dry matter* |
|---|---|---|---|---|
| Grue ................ | Larix decidua | 2.8±0.3 | 4.23±0.20 | 85.1±1.6 |
| | Picea abies | 3.8±0.4 | 4.18±0.05 | 85.9±2.4 |
| | Diff. | ÷1.0 | 0.05 | ÷0.8 |
| Eidsberg ........... | Larix sibirica | 5.8±0.4 | 4.86±0.04 | 10.5±1.0 |
| | Picea abies | 2.3±1.1 | 4.40±0.10 | 25.1±1.0 |
| | Diff. | 3.5 | 0.46** | ÷14.6*** |
| Ringsaker ........... | Larix sibirica | 2.8±1.1 | 4.52±0.35 | 13.7±0.7 |
| | Picea abies | 2.2±0.2 | 4.34±0.14 | 13.1±0.8 |
| | Diff. | 0.6 | 0.18 | 0.6 |
| Storelvdal .......... | Larix sibirica | 2.6±0.4 | 3.90±0.08 | 76.4±3.4 |
| | Pinus silvestris | 4.0±0.6 | 3.58±0.06 | 88.7±1.5 |
| | Diff. | ÷1.4 | 0.32* | ÷12.3* |
| Brunlanes ........... | Fagus silvatica | 7.8±1.0 | 3.90±0.39 | 79.7±5.6 |
| | Picea abies | 7.3±0.6 | 4.23±0.14 | 71.4±7.3 |
| | Diff. | 0.5 | ÷0.33 | 8.3 |
| Ås .................. | Larix leptolepis | 4.0 | 4.37±0.08 | 23.9±0.2 |
| | Fagus silvatica | 5.7±1.9 | 4.94±0.05 | 16.3±0.1 |
| | Diff. | ÷1.7 | ÷0.57*** | 7.6*** |

*Silicon.* The ash of the larch needles is richer in silicon than the ash of the Norway spruce needles. The silicon content in relation to the dry matter, on the other hand, gives no uniform picture. The larch needles are richer in silicon at Eidsberg than the spruce needles, but for the other plots there is no distinct difference.

*Ash.* The ash content in larch and Norway spruce needles varies in relation to each other from plot to plot. The larch needles are poorer in ash at Grue and at Ringsaker, but richer in ash at Eidsberg. Here also the silicon content was significantly highest in the larch needles.

These investigations show clearly the great danger which lies in drawing general conclusions from isolated analysis data regarding the capacity of the individual tree species to enrich the humus with nutrients. Especially in the case of potassium, phosphorus and nitrogen,

*of humus layer.* Table 10

| M-figure | L-figure | mg per 100 g dry matter | | per cent of organic matter | | C/N |
|---|---|---|---|---|---|---|
| | | $NH_4Cl$ soluble Ca | Inorganic P | Organic P | Total N | |
| 69.7± 6.7 | 27.3±0.4 | 289 | 11.4±0.6 | 0.118 | 1.86±0.11 | 27.2 |
| 133.3±11.1 | 37.8±3.8 | 439 | 13.1±5.7 | 0.100±0.016 | 1.49±0.04 | 34.0 |
| ÷63.6*** | ÷10.5 | ÷150 | ÷1.7 | 0.018 | 0.37** | ÷6.8 |
| 9.9±1.1 | 3.0±0.6 | 98 | 23.6±2.2 | 0.485±0.025 | 2.89±0.13 | 17.3 |
| 15.3±0.8 | 4.9±1.0 | 323 | 13.8±0.6 | 0.325±0.012 | 2.49±0.07 | 20.1 |
| ÷5.4** | ÷1.9 | ÷225 | 9.8** | 0.160** | 0.40* | ÷2.8 |
| 11.6±1.0 | 7.3±0.5 | 129 | 8.7±1.2 | 0.298±0.027 | 2.66±0.07 | 19.8 |
| 12.7±3.6 | 4.6±1.5 | 79 | 10.0±0.7 | 0.236±0.010 | 2.42±0.07 | 21.7 |
| ÷1.1 | 2.7 | 50 | ÷1.3 | 0.062 | 0.24* | ÷1.9 |
| 65 | 21.7±1.5 | 227 | 12.8±1.9 | 0.102±0.004 | 1.48±0.08 | 35.8 |
| 96.0±9.2 | 22.7±2.4 | 328 | 15.4±2.8 | 0.084±0.004 | 1.30±0.05 | 40.8 |
| ÷31 | ÷1.0 | ÷101 | ÷1.6 | 0.018* | 0.18 | ÷5.0 |
| 96.2±9.9 | 14.0±3.7 | 284 | 7.7±0.7 | 0.121±0.018 | 2.21±0.08 | 21.6 |
| 82.0±11.4 | 20.8±3.6 | 339 | 11.7±1.3 | 0.129±0.019 | 2.15±0.10 | 22.2 |
| 14.2 | ÷6.8 | ÷55 | ÷4.0** | ÷0.009 | 0.06 | ÷0.6 |
| 26.4±0.6 | 2.6±0.7 | 86.3±16.3 | 11.1±1.7 | 0.379±0.070 | 3.28±0.09 | 15.3 |
| 22.1±0.5 | 1.2±0.2 | 80.0±5.4 | 16.3±1.5 | 0.406±0.047 | 3.60±0.16 | 13.9 |
| 4.3** | 1.4 | 6.3 | ÷5.2 | ÷0.027 | ÷0.32 | 1.4 |

which are to a great extent relinquished by needles and leaves when they wither, the variation appears to be large and unpredictable. Particularly where potassium is concerned, the question of leaching comes in. This leaching can take place even before the litter falls. (TAMM 1951). This involves a degree of uncertainty with regard to the specified potassium quantity. The error is difficult to estimate, and the uncertainty is still greater if the litter is exposed to rain after it has fallen. It has not been possible to avoid this latter entirely in these investigations.

Calcium and silicon appeared from our investigations to show a lower degree of variation, and this is possibly due to the fact that these elements occur as incrusting substances.

Our material provides no reason to suppose that larch litter in general is richer than Norway spruce litter in the nutrients potassium, phosphorus and nitrogen. Larch litter proves to be poorer in calcium

and richer in magnesium than spruce litter. In the ash also, the calcium content is lower, while the magnesium and silicon contents are higher.

Table 10 shows that the average pH in the humus layer is lower in spruce stands than in larch stands, but the difference is significant only at Eidsberg. In this plot, the content of organic matter in the upper section of the humus layer is significantly higher in the spruce stand.

The M-figures are higher under spruce than under larch at Grue and Eidsberg.

Ammoniumchloride-soluble calcium also is higher under Norway spruce than under larch at Grue and Eidsberg. At Ringsaker the opposite is found. The marked difference found in the calcium content between larch needles and spruce needles is not, therefore, fully reflected in the humus.

At Eidsberg, the content of inorganic phosphorus is higher under larch than under spruce, which is also the case with the amount of phosphorus which is associated with the organic matter.

The nitrogen content, calculated as a percentage of the organic matter, is for all plots significantly higher in the larch stands than in the spruce stands, and rises in the order Grue—Ringsaker—Eidsberg. The C/N quotient varies from 19.8 at Eidsberg to 34.0 at Grue. This quotient is often employed as a measure of the quality of the humus. (Anderson and Byers 1934, Duchaufour 1950). There is no agreement between the C/N quotient and the expression for the rate of decomposition, so far as we have ascertained.

At Grue and Ringsaker, the larch is sowed or planted in old Norway spruce plantations. Here, presumably, very stable conditions prevail, and no marked effect can be expected from a new tree species. We find a difference in the nitrogen content of the humus, in that this is higher in larch stands in both places than in the corresponding spruce stands.

At Eidsberg, both Norway spruce and larch are planted on previously cultivated soil. Less stable conditions must be expected here, so that both tree species have the possibility to alter soil. The acidity in the humus layer here is significantly highest under spruce, and the same applies to the content of organic matter. The content of ammoniumchloride-soluble calcium also, and the M-figure are highest in the spruce humus, while the content of inorganic phosporus, organic phosphorus and nitrogen is highest under larch. On the whole, it must be said that the spruce appears to have altered the previous

conditions in the Eidsberg plot more than the larch. Our investigations, however, cannot provide the answer as to whether this more rapid alteration in the soil of the spruce stand is harmful or not.

In the larch stand we have a very varied and nutrient-demanding vegetation, while in the Norway spruce stand there is principally a close moss carpet. These circumstances undoubtedly play a major part in the development which has taken place. (See also section dealing with ground vegetation, p. 161).

2. *The plot at Storelvdal. Comparison between larch and Scots pine.*

a. Soil.

At Storelvdal, the subsoil is clay-free to slightly clayey medium sand with a high pH, from 5.80—6.06. According to the analysis figures, the plot is very uniform.

In both stands, the pH in the humus is very low, and significantly lowest in the pine humus, where the content of organic matter is highest, likewise the M-figure and the ammoniumchloride-soluble calcium. The organic phosphorus content, on the other hand, is highest in the larch humus, likewise the nitrogen content. The difference between larch and pine humus is significant for phosphorus, but not for nitrogen.

The high C/N figure in the pine humus is in poor agreement with the relatively quick decomposition which we found for the pine litter.

b. Litter.

The pine needles are much poorer in ash than the larch needles. The magnesium, potassium, phosphorus and silicon content is significantly lower in pine needles, while the calcium, manganese and nitrogen content shows no difference. It is worthy of notice that the phosphorus content in the larch needles here appears to be at least as high as on the better site classes at Grue, Eidsberg and Ringsaker.

Calculated as a percentage of the ash, it is shown that the calcium content dominates in the pine ash with up to 29.0 %. In the ash of the larch needles it is silicon which dominates, as is the case in the other larch stands.

3. *The plot at Brunlanes. Comparison between beech and Norway spruce.*

a. Soil.

The lowest layers in the profiles consist of clayey medium to

clayey coarse sand. On account of the high humus content in these layers, the pH is low, from 4.83 – 5.12.

The ammoniumchloride-soluble calcium content here is somewhat higher in the beech stand than in the spruce stand. In the spruce humus, the calcium content is slightly higher than in the beech humus.

The pH in the beech humus is very low, and lower than in the spruce humus, but the difference is not significant.

The content of inorganic phosphorus in the humus is highest in the spruce stand.

b. Litter.

Beech leaves are poorer than spruce needles in potassium, phosphorus and nitrogen, but richer in magnesium. In 1951–52, beech leaves are richer in calcium than spruce needles.

The ash of spruce needles is richer in potassium and phosphorus, and in 1952–53 it is also richer in silicon than the ash of the beech leaves, which is, on the other hand, richer in magnesium, and in 1951–52 also richer in calcium.

4. *The plot at Ås. Comparison between larch and beech.*

a. Soil.

The subsoil is clayey fine sand – clayey coarse sand. Higher in the profile there is less clay. This indicates that the morainic material is somewhat affected by water.

In the beech stand, the content of ammoniumchloride-soluble calcium in the subsoil is very high, much higher than in the larch stand. It is possible that this is due to a chance error while samples were being taken.

In the larch humus, the pH is significantly lower than in the beech humus. The content of organic matter is larger in the larch humus, likewise the M-figure.

The nitrogen content is higher in the beech humus than in the larch humus, but owing to the great standard error the difference is not significant.

If we compare the humus conditions under beech at Brunlanes with those found under beech at Ås, we find at Brunlanes a considerably higher content of organic matter and a lower pH. At Ås, we have a higher nitrogen content. It seems natural, therefore, to find at Ås a much higher decomposition rate for beech leaves than is found at Brunlanes.

b. Litter.

At Ås, we have three years' material to build upon. We see here that larch needles are poorer than beech leaves in all nutrients. The difference in the nitrogen content is not significant in 1948—49, but the other years show a three-star significance. The silicon content and the ash content also are higher in the beech leaves.

The calcium and potassium contents are highest in the ash of the beech leaves, while the phosphorus content shows no difference. Silicon dominates strongly in the ash from the larch needles.

The low potassium content for 1952—53 is remarkable. The snow came unexpectedly that year, before the fall of litter was completed. Part of the litter, therefore, was left lying during the winter, and this is presumably the reason for the low potassium values.

Since the site class at Ås is high, something which is evinced by the high nutrient content in the beech leaves, the low nutrient content in the larch needles may appear surprising. We have here Japanese larch, and although one plot is not much to build upon, it is possible that the needle litter of this larch species lies on a lower nutrient level than for European and Sibirian larch. We must always take into consideration that the various species can differ also in this respect. It is therefore possible that it is wrong to put the material from Grue together with the material from Eidsberg and Ringsaker, as has been done in the description above.

———

VIRO (1955) treats especially the large quantities of silica which are introduced into the humus by means of the litter from larch and Norway spruce, and the possible influence of this on the formation of raw humus. As mentioned previously, EBERMEYER (1876) and KRAUSS (1926) handle the possible influence of the silica on the decomposition of the litter.

Our investigations show that the silicon content in the main litter from beech, larch and Norway spruce is of the same magnitude, while the silicon content in Scots pine needles is very low.

In the case of Norway spruce, there seems to be a faint connection between the calcium and silicon content in the ash, in that the silicon content decreases as the calcium content rises. No such connection can be observed for larch. If the tree species are compared one with another, the result is that Scots pine shows a very high calcium/silicon ratio, beech and Norway spruce take a middle position, while larch has a low calcium/silicon ratio.

Table 11. *Chemical composition of residual litter.*

| Plot | Year 19– | Tree species | Percentage of dry matter | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ca | Mg | Mn | K | P | N | Si | Ash |
| Grue ...... | 51–52 | Larix decidua | 0.38 | 0.053 | 0.101 | 0.09 | 0.037 | 0.66 | 0.15 | 1.88 |
| | | Picea abies .... | 0.62 | 0.062 | 0.073 | 0.14 | 0.079 | 0.90 | 0.36 | 3.03 |
| | 52–53 | Larix decidua | 0.42 | 0.054 | 0.144 | 0.15 | 0.075 | 0.71 | 0.35 | 2.92 |
| | | Picea abies .... | 0.49 | 0.041 | 0.088 | 0.15 | 0.123 | 1.15 | 0.44 | 3.26 |
| Eidsberg .. | 51–52 | Larix sibirica | 0.36 | 0.065 | 0.040 | 0.17 | 0.050 | 0.88 | 0.21 | 1.96 |
| | | Picea abies | 0.39 | 0.060 | 0.158 | 0.18 | 0.114 | 1.24 | 0.71 | 3.66 |
| | 52–53 | Larix sibirica | 0.34 | 0.070 | 0.031 | 0.16 | 0.094 | 1.41 | 0.52 | 3.79 |
| | | Picea abies | 0.42 | 0.059 | 0.036 | 0.14 | 0.066 | 1.43 | 0.70 | 4.00 |
| Ringsaker .. | 51–52 | Larix sibirica | 0.18 | 0.044 | 0.021 | 0.11 | 0.031 | 0.48 | 0.11 | 1.09 |
| | | Picea abies | 0.56 | 0.057 | 0.064 | 0.16 | 0.062 | 1.14 | 0.51 | 3.53 |
| | 52–53 | Larix sibirica | 0.31 | 0.060 | 0.042 | 0.19 | 0.061 | 0.79 | 0.28 | 2.30 |
| | | Picea abies | 0.47 | 0.059 | 0.064 | 0.15 | 0.152 | 1.41 | 1.12 | 4.92 |
| Storelvdal .. | 51–52 | Larix sibirica | 0.29 | 0.060 | 0.024 | 0.10 | 0.049 | 0.70 | 0.56 | 2.07 |
| | | Pinus silvestris | 0.23 | 0.030 | 0.049 | 0.06 | 0.007 | 0.38 | 0.35 | 1.18 |
| | 52–53 | Larix sibirica | 0.40 | 0.062 | 0.076 | 0.13 | 0.069 | 0.63 | 0.42 | 2.70 |
| | | Pinus silvestris | 0.25 | 0.036 | 0.018 | 0.08 | 0.044 | 0.68 | 0.09 | 1.21 |
| Brunlanes .. | 51–52 | Fagus silvatica | 0.54 | 0.070 | 0.073 | 0.06 | 0.049 | 0.84 | 0.31 | 2.68 |
| | | Picea abies | 0.22 | 0.050 | 0.040 | 0.14 | 0.071 | 0.82 | 0.26 | 1.83 |
| | 52–53 | Fagus silvatica | 0.52 | 0.069 | 0.065 | 0.10 | 0.063 | 1.02 | 0.33 | 3.24 |
| | | Picea abies | 0.14 | 0.043 | 0.043 | 0.20 | 0.044 | 0.62 | 0.21 | 1.97 |
| Ås ........ | 51–52 | Laris leptolepis | 0.89 | | | 0.11 | 0.043 | 0.56 | 0.12 | 2.21 |
| | | Fagus silvatica | 0.58 | | | 0.17 | 0.038 | 0.74 | 0.25 | 2.62 |
| | 52–53 | Larix leptolepis | 0.42 | 0.138 | 0.075 | 0.12 | 0.036 | 0.68 | 0.39 | 2.53 |
| | | Fagus silvatica | 0.62 | 0.116 | 0.101 | 0.10 | 0.027 | 0.53 | 0.14 | 2.21 |

Table 12. *Chemical composition of other litter for the year 1952-53*

| Plot | Tree species | percentage of dry matter | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ca | K | P | N | Si | Ash |
| Grue ............ | Larix decidua | 0.74 | 0.09 | 0.066 | 0.70 | 0.38 | 3.45 |
| | Picea abies | 0.52 | 0.09 | 0.077 | 0.72 | 0.39 | 2.94 |
| Eidsberg ........ | Larix sibirica | 1.06 | 0.43 | 0.155 | 1.50 | 0.65 | 7.01 |
| | Picea abies | – | – | – | – | – | – |
| Ringsaker ........ | Larix sibirica | 0.91 | 0.10 | 0.097 | 0.99 | 0.81 | 4.28 |
| | Picea abies | 0.60 | 0.23 | 0.058 | 1.00 | 0.82 | 4.32 |
| Storelvdal ........ | Larix sibirica | 0.43 | 0.07 | 0.048 | 0.61 | 0.10 | 2.09 |
| | Pinus silvestris | 0.42 | 0.12 | 0.101 | 0.95 | 0.80 | 3.56 |
| Brunlanes ........ | Fagus silvatica | 0.58 | 0.10 | 0.091 | 1.01 | 0.88 | 4.84 |
| | Picea abies | 0.75 | 0.11 | 0.075 | 1.22 | 0.79 | 4.98 |
| Ås .............. | Larix leptolepis | 1.10 | 0.17 | 0.098 | 1.70 | 0.69 | 5.17 |
| | Fagus silvatica | 0.91 | 0.17 | 0.130 | 1.29 | 1.79 | 11.23 |

## VII. Chemical composition of residual litter and other litter.

Tables 11 and 12 show the chemical composition of residual litter and other litter. Since this litter is heterogeneous, there is a much greater variation in the chemical composition. On the whole, this litter is poorer in nutrients than the corresponding main litter, although we find numerous exceptions. Mention can be made, for instance, of the high calcium content in the residual litter from the larch stand at Ås, and likewise the high nitrogen content from the spruce stands at Eidsberg and Ringsaker.

## VIII. Nutrient quantities returned annually to the soil by litter.

Quite significant quantities of nutrients are added to the soil every year by means of forest litter. Table 13 shows the amount of each particular element which is contributed each year by main litter and residual litter, in other words, by the total amount of litter from the main tree species in the stands under investigation. The figures apply to kg. per hectare, and are calculated on the basis of the litter yield and the nutrient content of the litter. .

Here again, there are naturally very considerable variations from

Table 13. *Nutrient quantities returned annually to the soil by main- and residual litter.* Kg. per hectare.

| *Plot* | *Year* | *Tree species* | *Litter* | Ca | Mg | Mn | K | P | N | Si |
|---|---|---|---|---|---|---|---|---|---|---|
| Grue ...... | 51–52 | Larix decidua | Main | 12.5±0.6 | 2.7±0.1 | 4.4±0.4 | 2.0±0.1 | 1.6±0.1 | 12.3±0.5 | 17.1±0.8 |
| | | | Residual | 1.3±0.6 | 0.2±0.1 | 0.3±0.2 | 0.3±0.1 | 0.1±0.1 | 2.2±1.0 | 0.5±0.2 |
| | | | | 13.8 | 2.9 | 4.7 | 2.3 | 1.7 | 14.5 | 17.6 |
| | | Picea abies | Main | 16.9±1.3 | 1.3±0.1 | 3.3±0.3 | 2.4±0.2 | 1.5±0.1 | 11.9±0.8 | 13.9±1.0 |
| | | | Residual | 1.6±0.2 | 0.2±0.0 | 0.2±0.0 | 0.4±0.1 | 0.2±0.0 | 2.3±0.3 | 0.9±0.1 |
| | | | | 18.5 | 1.5 | 3.5 | 2.8 | 1.7 | 14.2 | 14.8 |
| Eidsberg .. | 51–52 | Larix sibirica | Main | 14.5±0.8 | 4.4±0.2 | 0.9±0.0 | 3.3±0.2 | 1.9±0.3 | 24.3±0.8 | 26.2±1.3 |
| | | | Residual | 2.3±0.7 | 0.4±0.1 | 0.3±0.1 | 1.1±0.3 | 0.3±0.1 | 5.6±1.7 | 1.3±0.4 |
| | | | | 16.8 | 4.8 | 1.2 | 4.4 | 2.2 | 29.9 | 27.5 |
| | | Picea abies | Main | 22.2±1.4 | 2.7±0.1 | 2.4±0.1 | 5.1±0.2 | 2.6±0.1 | 27.0±0.9 | 26.0±1.4 |
| | | | Residual | 1.7±0.2 | 0.3±0.0 | 0.7±0.1 | 0.8±0.1 | 0.5±0.0 | 5.4±0.5 | 3.1±0.3 |
| | | | | 23.9 | 3.0 | 3.1 | 5.9 | 3.1 | 32.4 | 29.1 |
| | 52–53 | Larix sibirica | Main | 12.4±0.5 | 3.7±0.1 | 1.0±0.0 | 3.6±0.2 | 2.4±0.1 | 29.5±0.8 | 31.4±1.0 |
| | | | Residual | 1.5±0.2 | 0.3±0.0 | 0.1±0.0 | 0.7±0.1 | 0.4±0.1 | 6.3±1.0 | 2.3±0.4 |
| | | | | 13.9 | 4.0 | 1.1 | 4.3 | 2.8 | 35.8 | 33.7 |
| | | Picea abies | Main | 25.2±2.3 | 2.8±0.3 | 2.7±0.3 | 4.0±0.4 | 3.0±0.3 | 34.7±3.2 | 29.2±2.7 |
| | | | Residual | 2.0±0.4 | 0.3±0.1 | 0.2±0.0 | 0.7±0.1 | 0.3±0.1 | 6.9±1.5 | 3.4±0.7 |
| | | | | 27.2 | 3.1 | 2.9 | 4.7 | 3.3 | 41.6 | 32.6 |

Table 13 continued

| *Plot* | *Year* | *Tree species* | *Litter* | Ca | Mg | Mn | K | P | N | Si |
|---|---|---|---|---|---|---|---|---|---|---|
| Ringsaker .. | 51–52 | Larix sibirica | Main | 12.5±0.5 | 4.6±0.2 | 1.6±0.1 | 3.3±0.2 | 1.7±0.1 | 14.5±0.6 | 19.2±0.7 |
| | | | Residual | 1.3±0.3 | 0.3±0.1 | 0.2±0.0 | 0.8±0.2 | 0.2±0.1 | 3.5±0.9 | 0.8±0.2 |
| | | | | 13.8 | 4.9 | 1.8 | 4.1 | 1.9 | 18.0 | 20.0 |
| | | Picea abies | Main | 21.2±2.2 | 1.7±0.2 | 2.0±0.3 | 2.7±0.3 | 1.8±0.2 | 16.0±1.6 | 17.0±1.8 |
| | | | Residual | 0.6±0.1 | 0.1±0.0 | 0.1±0.0 | 0.2±0.0 | 0.1±0.0 | 1.2±0.2 | 0.5±0.1 |
| | | | | 21.8 | 1.8 | 2.1 | 2.9 | 1.9 | 17.2 | 17.5 |
| | 52–53 | Larix sibirica | Main | 9.5±0.4 | 2.4±0.1 | 1.2±0.1 | 1.8±0.1 | 1.7±0.1 | 19.1±0.9 | 18.8±0.6 |
| | | | Residual | 2.3±0.5 | 0.4±0.1 | 0.3±0.1 | 1.4±0.3 | 0.4±0.1 | 5.8±1.3 | 2.1±0.5 |
| | | | | 11.8 | 2.8 | 1.5 | 3.2 | 2.1 | 24.9 | 20.9 |
| | | Picea abies | Main | 21.6±1.9 | 1.4±0.1 | 2.3±0.2 | 2.5±0.3 | 1.7±0.1 | 16.5±1.4 | 18.0±1.5 |
| | | | Residual | 1.4±0.2 | 0.2±0.0 | 0.2±0.0 | 0.4±0.1 | 0.5±0.1 | 4.2±0.6 | 3.3±0.5 |
| | | | | 23.0 | 1.6 | 2.5 | 2.9 | 2.2 | 20.7 | 21.3 |
| Storelvdal .. | 51–52 | Larix sibirica | Main | 2.7±0.2 | 1.0±0.1 | 0.8±0.2 | 0.7±0.1 | 0.6±0.1 | 3.0±0.2 | 5.3±0.4 |
| | | | Residual | 0.4±0.1 | 0.1±0.0 | 0.0±0.0 | 0.1±0.0 | 0.1±0.0 | 1.0±0.2 | 0.8±0.2 |
| | | | | 3.1 | 1.1 | 0.8 | 0.8 | 0.7 | 4.0 | 6.1 |
| | | Pinus silvestris | Main | 8.7±0.9 | 1.1±0.6 | 2.3±0.4 | 1.3±0.1 | 0.6±0.0 | 8.3±0.2 | 2.0±0.4 |
| | | | Residual | 1.7±0.2 | 0.2±0.0 | 0.4±0.0 | 0.4±0.1 | 0.1±0.0 | 2.8±0.4 | 2.6±0.4 |
| | | | | 10.4 | 1.3 | 2.7 | 1.7 | 0.7 | 11.1 | 4.6 |
| | 52–53 | Larix sibirica | Main | 3.1±0.3 | 1.1±0.1 | 1.0±0.2 | 0.8±0.1 | 0.8±0.1 | 4.0±0.3 | 6.6±0.6 |
| | | | Residual | 1.1±0.3 | 0.2±0.0 | 0.2±0.1 | 0.3±0.1 | 0.2±0.1 | 1.7±0.5 | 1.1±0.3 |
| | | | | 4.2 | 1.3 | 1.2 | 1.1 | 1.0 | 5.7 | 7.7 |
| | | Pinus silvestris | Main | 7.1±0.6 | 0.8±0.1 | 1.7±0.3 | 0.8±0.0 | 0.5±0.0 | 8.7±0.5 | 1.4±0.1 |
| | | | Residual | 1.8±0.3 | 0.2±0.0 | 0.1±0.0 | 0.6±0.1 | 0.3±0.0 | 4.9±0.7 | 0.6±0.1 |
| | | | | 8.9 | 1.0 | 1.8 | 1.4 | 0.8 | 13.6 | 2.0 |

Table 13 continued

| *Plot* | *Year* | *Tree species* | *Litter* | Ca | Mg | Mn | K | P | N | Si |
|---|---|---|---|---|---|---|---|---|---|---|
| Brunlanes .. | 51.52 | Fagus silvatica | Main | 18.6±0.9 | 2.1±0.1 | 2.8±0.3 | 2.1±0.1 | 1.1±0.1 | 16.0±0.8 | 16.6±1.4 |
| | | | Residual | 2.1±0.2 | 0.3±0.1 | 0.3±0.0 | 0.2±0.0 | 0.2±0.0 | 3.3±0.4 | 1.2±0.1 |
| | | | | 20.7 | 2.4 | 3.1 | 2.3 | 1.3 | 19.3 | 17.8 |
| | | Picea abies | Main | 25.8±2.3 | 2.7±0.1 | 4.9±0.4 | 5.3±0.3 | 2.8±0.1 | 31.0±1.1 | 27.6±1.8 |
| | | | Residual | 2.1±0.5 | 0.5±0.1 | 0.4±0.1 | 1.3±0.3 | 0.7±0.2 | 7.7±2.0 | 2.4±0.6 |
| | | | | 27.9 | 3.2 | 5.3 | 6.6 | 3.5 | 38.7 | 30.0 |
| | 52–53 | Fagus silvatica | Main | 26.0±1.4 | 2.8±0.2 | 5.7±0.3 | 2.3±0.2 | 2.0±0.1 | 24.2±1.3 | 22.8±1.4 |
| | | | Residual | 1.0±0.2 | 0.1±0.0 | 0.1±0.0 | 0.2±0.0 | 0.1±0.0 | 1.9±0.4 | 0.6±0.1 |
| | | | | 27.0 | 2.9 | 5.8 | 2.5 | 2.1 | 26.1 | 23.4 |
| | | Picea abies | Main | 28.1±2.0 | 2.4±0.1 | 5.6±0.4 | 4.5±0.4 | 2.8±0.2 | 30.1±1.4 | 29.1±1.7 |
| | | | Residual | 1.8±0.6 | 0.6±0.2 | 0.6±0.2 | 2.6±0.9 | 0.6±0.2 | 8.1±2.8 | 2.7±1.0 |
| | | | | 29.9 | 3.0 | 6.2 | 7.1 | 3.4 | 38.2 | 31.8 |
| Ås ...... . | 48–49 | Larix leptolepis | Main | 6.6±0.4 | | | 1.4±0.1 | 0.7±0.2 | 13.1±0.8 | 17.6±0.9 |
| | | Fagus silvatica | Main | 25.7±2.0 | | | 6.6±0.5 | 1.5±0.1 | 22.5±1.9 | 30.9±2.2 |
| | 51–52 | Larix leptolepis | Main | 13.5±1.0 | 3.2±0.2 | 0.8±0.2 | 2.6±0.2 | 0.8±0.1 | 17.2±1.2 | 24.3±1.7 |
| | | | Residual | 5.4±2.6 | | | 0.7±0.3 | 0.3±0.1 | 3.4±1.6 | 0.7±0.3 |
| | | | | 18.9 | | | 3.3 | 1.1 | 20.6 | 25.0 |
| | | Fagus silvatica | Main | 37.0±1.9 | 5.5±0.2 | 3.2±0.3 | 10.3±0.8 | 2.2±0.2 | 35.6±1.6 | 35.1±0.8 |
| | | | Residual | 0.5±0.1 | | | 0.1±0.0 | 0.0±0.0 | 0.6±0.1 | 0.2±0.0 |
| | | | | 37.5 | | | 10.4 | 2.2 | 36.2 | 35.3 |
| | 52–53 | Larix leptolepis | Main | 13.4±1.1 | 2.2±0.1 | 1.4±0.1 | 1.8±0.1 | 1.3±0.1 | 28.5±1.6 | 30.8±1.6 |
| | | | Residual | 2.3±0.7 | 0.7±0.2 | 0.4±0.1 | 0.6±0.2 | 0.2±0.1 | 3.7±1.6 | 2.1±0.7 |
| | | | | 15.7 | 2.9 | 1.8 | 2.4 | 1.5 | 32.2 | 32.9 |
| | | Fagus silvatica | Main | 34.5±1.3 | 3.9±0.2 | 3.6±0.2 | 3.5±0.4 | 2.0±0.2 | 39.3±1.8 | 34.1±1.9 |
| | | | Residual | 4.1±1.1 | 0.8±0.2 | 0.7±0.2 | 0.7±0.2 | 0.2±0.0 | 3.5±0.9 | 0.9±0.2 |
| | | | | 38.6 | 4.7 | 4.3 | 4.2 | 2.2 | 42.8 | 35.0 |

one year to another, and between the various tree species. On the whole, it is nitrogen which is contributed in the largest quantities, up to 42.8 kg. per hectare. Both calcium and silicon are also added in large quantities, respectively 38.6 and 35.3 kg. per hectare. It is interesting to notice that all three figures are found in the young and dense beech stand at Ås.

The relatively large quantities of manganese which are added are noteworthy.

## IX. Ground vegetation.

So far as the effect of the fall of litter on the soil is concerned, one must also take into consideration the litter which is contributed by the ground vegetation. It is obvious that this will vary to a considerable extent in the different stands under different tree species.

As mentioned in the section dealing with methods, we have tried to form an idea as to the quantities of ground vegetation litter which might be expected in these investigations. The results appear in table 14, where both dry matter and the individual nutrients are shown in kg. per hectare. So far as the composition of the ground vegetation in the different places is concerned, reference should be made to the description of the stands in Chapter II (page 119 seq.).

Since the collected material is so scanty, the results should naturally not have too much stress laid upon them. Neither have we attempted to reach any conclusion regarding what is added from the moss covering, which constitutes an important part of the ground vegetation

Table 14. *Yield of dry matter and nutrients from ground vegetation litter.*

| *Plot* | *Tree species* | *Kg per hectare* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Dry matter* | Ca | Mg | Mn | K | P | N | Si |
| Eidsberg ...... | Larix sibirica | 214 | 1.0 | 0.5 | 0.1 | 2.9 | 0.5 | 3.6 | 6.7 |
| | Picea abies | 32 | 0.4 | 0.1 | 0.0 | 1.1 | 0.2 | 0.7 | 0.9 |
| Ringsaker ...... | Larix sibirica | 161 | 1.2 | 0.5 | 0.1 | 2.5 | 0.4 | 2.5 | 2.7 |
| | Picea abies | 50 | 0.3 | 0.1 | 0.0 | 0.8 | 0.1 | 0.8 | 0.8 |
| Storelvdal ...... | Larix sibirica | 108 | 0.8 | 0.1 | 0.1 | 0.2 | 0.1 | 1.7 | 0.3 |
| | Pinus silvestris | 162 | 1.3 | 0.2 | 0.2 | 0.3 | 0.1 | 1.6 | 0.2 |
| Brunlanes ...... | Fagus silvatica | – | – | – | – | – | – | – | – |
| | Picea abies | 204 | 1.1 | 0.5 | 0.1 | 3.8 | 0.4 | 3.1 | 1.3 |
| Ås ........... | Fagus silvatica | – | – | – | – | – | – | – | – |
| | Larix leptolepis | 301 | 1.8 | 0.3 | 0.3 | 3.3 | 0.5 | 5.8 | 6.0 |

on several of our plots. Investigations made by Romell (1934) and Tamm (1953) show that large quantities of organic matter can be produced annually in a dense carpet of moss.

Otherwise, our results agree quite well with previous investigations. Romell (1939) has found, in the case of north Sweden, an annual production of blueberry leaves amounting to approximately 220 kg. per hectare. Mork (1945) has a much higher figure for this litter production, but his investigations are concerned with areas where dwarf shrub is the dominant vegetation. In our investigations, however, we have very little dwarf shrub on the plots, so that no direct basis of comparison can be obtained here.

Scott (1955) found in a stand of *Pinus strobus* and various broad-leaved trees a litter yield from the ground vegetation nearly corresponding to what we have found.

It is noteworthy that the ground vegetation in our stands appears to have relatively little significance as a source of litter, so far as weight is concerned. Quantitatively, this would appear to be almost equivalent to that for «other litter». It is also obvious that the ground vegetation plays a much larger part in larch stands than in Norway spruce and beech stands.

The litter from ground vegetation has quite a high nutrient content, and the added quantities of nutrient elements are relatively large. This agrees well with Scott (1955), who maintains that the ground litter can play an important part in the nutrient cycle because of the high content of many nutrient elements. This circumstance has undoubtedly an influence, and complicates an investigation where one seeks to set the fall of litter from the trees in relation to the soil conditions.

## X. Discussion of certain findings.

pH, organic phosphorus and the C/N quotient are usually regarded as good indications of the humus condition. If these are used as a basis for the appraisal of the humus in the stands under investigation, there would appear to be a tendency for the humus conditions under larch to be more favourable than under Norway spruce and Scots pine. There is less material for beech, but the results do not indicate that there is any fundamental difference between this tree species and Norway spruce. The humus condition at Ås appears to be better under beech than under the Japanese larch.

Here, however, it must be pointed out that the differences which

are found are not always significant. Further, it must be noted that the differences registered are of far less magnitude than the difference found from plot to plot, and which must be attributed to the local conditions. The investigation shows, on the whole, that great care should be taken in branding a tree species as «soil-improving» or «soil-deteriorating» solely on the basis of the quantity and quality of the litter. If one compares previous investigations, it is also clearly shown how these can change from one place to another and from year to year.

It is reasonable to assume that the chemical conditions in the soil will influence the composition of the litter. We have, however, not been able to prove any connection in our material, apart from the humus, but in this case it is difficult to distinguish between cause and effect.

Neither should one disregard the possibility that there can be differences between the species within the same genus, perhaps just as large as between entirely different tree species. The present material from Ås regarding Japanese larch, compared with the results from Sibirian and European larch, suggest that the first-mentioned perhaps produces a poorer quality of litter than other larch species.

The effect on the soil of a particular tree species depends also undoubtedly on the character of the stand. When, for example, larch is so often regarded as especially fabourable, presumably this is due not least to the open structure of the larch stand. Light, warmth and moisture gain access in a much greater degree than in a Norway spruce stand. This makes possible a rich ground vegetation, which can provide valuable litter, and the decomposition of all litter takes place rapidly, so that good humus conditions are obtained.

## XI. Summary.

This investigation has been carried out to illuminate the following problems: —

1. What quantities of litter are produced annually by beech and larch?
2. What is the nutrient content of this litter?
3. How quickly does it decompose?
4. What effect on the soil has the litter from larch and beech?
5. How do the above-mentioned conditions for larch and beech compare with the conditions for our common tree species, Norway spruce and Scots pine?

In addition to the above, an attempt has been made to estimate the significance of the ground vegetation as a source of litter.

The investigation covers six plots in eastern Norway, and was carried out in 1951—52 and 1952—53, also in 1948—49 in the case og one plot. The following tree species were investigated: — *Larix decidua* Mill., *Larix sibirica* Ledeb., *Larix leptolepis* (Sieb. & Zucc.) Gord. and *Fagus silvatica* L. In five instances, additional plots have been laid out in neighbouring stands of *Picea abies* (L.) Karst. or *Pinus silvestris* L., for purposes of comparison. A description of the plots and stands is tabulated in table 1 (p.121) and table 2 (p.123).

The litter is collected by means of tin pots, and sorted into the following categories: —

*Main litter,* consisting of needles or leaves of the main tree species in the stand being investigated.

*Residual litter,* comprising all other litter from the main tree species (twigs, cones, bark, etc.)

*Other litter,* which is forest litter not originating from the main tree species.

The collected litter were analysed for calcium, magnesium, manganese, potassium, phosphorus, nitrogen and silicon. A description was made of the soil, and chemical analyses taken from each layer. The number of trees, the basal area and the volume were determined in the stands.

The principal results are as follows: —

1. The yield of litter varies considerably from year to year (table 3, p. 132). There is a clear connection between the yield of litter and the density of the stand, expressed as basal area, (fig. 1, p. 131). Main litter is predominant in the collected litter, in the majority of cases amounting to over 70 % (table 4, p. 133).
2. The total litter stock, seen in relation to the annual yield, lies throughout higher under Norway spruce than under larch, and higher under larch than under Scots pine and beech (table 5, p. 135).
3. The element content of the litter (table 6, p. 138, table 7, p. 142), and fig. 3, 4 and 5, pp. 140—44) varies considerably, not only amongst the plots but within the individual stand an from one year to another. Larch needles are poorer in calcium than Norway spruce needles, and also, as a rule, in manganese, but richer in magnesium. The ash from larch needles is also richer in silicon. There is no clear tendency for the remaining elements.

   Scots pine needles are poorer in ash than larch needles, and

the content of magnesium, potassium, phosphorus and silicon is lower in the pine needles. The remaining elements show no difference. The calcium content is dominant in the ash of the pine needles.

Beech leaves are poorer in potassium, phosphorus and nitrogen than Norway spruce needles, but richer in magnesium. Larch needles at Ås are poorer than beech leaves in all elements. The ash content also is lower in larch needles.

4. The soil conditions are shown in tables 8 (p. 146), 9 (p. 148) and 10 (p. 150). In our material, we have not been able to demonstrate any connection between the chemical conditions in the soil and the constituents of the litter, apart from the humus. The humus conditions seem to be more favourable under larch than under Norway spruce and Scots pine.
5. «Residual litter» and «other litter» show greater variation in chemical composition than main litter (table 11, p. 156 and table 12, p. 157). On the whole, these litters are poorer in nutrients.
6. The litter supplements the soil with a considerable amount of nutrients every year (table 13, p. 158). On the whole, it is nitrogen which is supplied in the largest quantities, but calcium and silicon can also show very high yields.
7. The grund vegetation litter, excluding the litter from mosses, which was not included in the investegation, forms only a small percentage of the yield of litter from the trees. This litter from the ground vegetation has, however, a comparatively high nutrient content, and can therefore play a certain part in the supply of nutriment to the humus (table 14, p. 161). The quantity of ground vegetation litter is larger under larch than under Norway spruce, and larger under spruce than under beech.

Con. Bonnevie-Svendsen Odd Gjems.

## References.

ANDERSON, M. S. and H. G. BYERS, 1934. The carbon-nitrogen ratio in relation to soil classification. Soil Sci. 38.

AALTONEN, V. T., 1948. Boden und Wald unter besonderer Berücksichtigung des nordeuropäischen Waldbaus. Berlin und Hamburg.

ALBERT, R., 1928. Die sogenannten Bodenerkrankungen, ihr Wesen, ihre Ursachen und Bedeutung für die Forstwirtschaft. Jber. dtsch. Forstver.

BURGER, H., 1945. Holz, Blattmenge und Zuwachs. VII. Mitteilung. Die Lärche. Mitt. Schweiz. Centralanst. forstl. Versuchsw. 24.

CHENG, K. L. and R. H. BRAY, 1951. Determination of calcium and magnesium in soil and plant material. Soil Sci. 72.

CHENG, K. L., S. W. MELSTAD and R. H. BRAY, 1953. Removing interfering metals in the versenate determination of calcium and magnesium. Soil Sci. 75.

COUNCLER, C., 1883. Untersuchungen über Waldstreu. I. Aschenanalysen von Buchenlaubstreu, verbunden mit Untersuchungen der zugehörigen Böden. Z. Forst-u. Jagdw. 15.

COUNCLER, C., 1903. Aschenanalysen von dreijährigen gedüngten Fichten. Ibid. 35.

DAMSGAARD-SØRENSEN, P., 1947. Studier over Jordens Fosforsyreindhold IV. Det organisk bundne Fosfor. Tidsskr. Planteavl, 50.

DUCHAUFOUR, P. [1950?] Note sur les types d'humus forestier et leur rapport carbone/azote (C/N). International congress of soil science, 4th. Amsterdam 1950. Transactions 2.

EBERMEYER, E., 1876. Die gesamte Lehre der Waldstreu. Berlin.

EGNÉR, H., 1940. Bestimmung der Kalibedürftigkeit des Bodens auf chemischem Wege. Bodenk. u. Pflanzenernähr. 21/22, (66/67).

EGNÉR, H., G. KÖHLER and F. NYDAL, 1938. Die Laktatmethode zur Bestimmung leichtlöslicher Phosphorsäure in Ackerböden. Kungl. Lantbrukshögskol. Ann. 6.

GJEMS, O., 1956. Complexometric determination of calcium, magnesium and manganese in plant material and soils. In manuscript.

GJEMS, O. and D. LYDERSEN, 1954. Entfernung von Aluminium bei der flammenphotometrischen Bestimmung von Calcium. Z. Pflanzenernähr. Düng. Bodenk. 64 (109).

HANDLEY, W. R. C., 1954. Mull and mor formation in relation to forest soils. Bull. For. Comm. Lond. No. 23.

HARTMANN, F. K., 1932. Aufbau, Verbreitung und Haushalt natürlicher Fichtenwaldgesellschaften. Forstarchiv 8.

HERRMANN, R., P. LEDERLE and O. VON METZEN, 1943. Untersuchung über die von W. Bonewitz beobachtete «Dehydratisierung» der Phosphorsäure in Keimpflanzenaschen. Bodenenk. u. Pflanzenernähr. 32.

HESSELMAN, H., 1926. Studier över barrskogens humustäcke, dess egenskaper och beroende av skogsvården. Medd. Stat. skogsförsöksanst. Stockh. 22.

INTERNATIONAL CONGRESS OF SOIL SCIENCE, 2ND. Leningrad-Moscow 1930. Conclusions of the First Commission. Proceedings and Papers. I, p XXIV.

[KNUTSON, K.] p. 182–185 in: MALMSTRÖM, C.,1949. Studier över skogstyper och trädslagsfördelning innom Västerbottens län. Medd. Stat. skogsforskningsinst. 37.

KRAUSS, G., 1926. Über die Schwankungen des Kalkgehaltes im Rotbuchenlaub auf verschiedenem Standort. Forstwiss. Cbl. 48 (70).

KRAUSS, G., F. HÄRTEL, K. MÜLLER, G. GÄRTNER, H. SCHANZ et al., 1939. Standortsgemässe Durchführung der Abkehr von der Fichtenwirtschaft im nordwestsächsischen Niederland. Tharandt. forstl. Jb. 90.

LEININGEN-WESTERBURG, W. GRAF ZU, 1926. Humuszehrer. Forstwiss. Cbl. 48 (70).

LEININGEN-WESTERBURG, W. GRAF ZU, 1931. Forstwirtschaftliche Bodenbearbeitung, Düngung und Einwirkung der Waldwegetation auf den Boden. Blank's Handbuch der Bodenlehre 9. Berlin.

LINDBERG, S. and H. NORMING, 1943. Om produktionen av barrförna och densammas sammansättning i ett granbestånd invid Stockholm. Sv. Skogsvårdsför. tidskr. 41.

MATTSON, S. and E. KOUTLER-ANDERSSON, 1941. The acid-base condition in vegetation, litter and humus I. Acids, acidoids and bases in relation to decomposition. Kungl. Lantbrukshögskol. Ann. 9.

MIKOLA, P., 1954. Kokeellisia tutkimuksia metsäkarikkeiden hajaantumisnopeudesta. Summary: Experiments on the rate of decomposition of forest litter. Commun. Inst. for. Fenn. 43. 1.

MORK, E., 1942. Om strøfallet i våre skoger. Medd. norske Skogforsøksv. VIII.

MORK, E., 1945. Om skogbunnens lyngvegetasjon. Ibid. IX.

MØLLER, C. M., 1945. Untersuchungen über Laubmenge, Stoffverlust und Stoffproduktion des Waldes. Forstl. Forsøgsv., Danm. 17.

RAMANN, E., 1898. Untersuchung streuberechter Böden. Z. Forst- u. Jagdw. 30.

ROMELL, L.-G., 1932. Mull and duff as biotic equilibria. Soil Sci. 34.

ROMELL, L.-G., 1939. Den nordiska blåbärsgranskogens produktion av ris, mossa och förna. Svensk bot. tidskr. 33.

RUBNER, K., 1932. Holzartenwechsel. Forstarchiv 8.

SCHEEL, K. C., 1935. Die colorimetrische Bestimmung der Phosphorsäure in Düngmitteln mit dem Pulfrich-Photometer. Z. anal. Chem. 105.

SCHÜTZE, W., 1876. Ueber den Aschengehalt und über die Zusammensetzung der Asche von Pinus sylvestris. Z. Forst- u. Jagdw. 8.

SCOTT, D. R. M., 1955. Amount and chemical composition of the organic matter contributed by overstory and understory vegetation to forest soil. Bull. Yale Sch. For. No. 62.

TAMM, C. O., 1951. Removal of plant nutrients from tree crowns by rain. Physiol. Plant., Copenhagen, 4.

TAMM, C. O., 1953. Growth, yield and nutrition in carpets of a forest moss (Hylocomium splendens). Medd. Stat. skogsforskningsinst. 43.

TAMM, O., 1930. Om brunjorden i Sverige. Sv. skogsvårdsför. tidskr. 28.

TAMM, O., 1934. Om mekanisk analys av svenska skogsjordar. Medd. Stat. skogsförsöksanst. 27.

TAMM, O. and E. WADMAN, 1945. Om skogens naturliga betingelser i Hamra revir. Bilaga till. Sv. skogsvårdsför. tidskr. 2 [43].

TÜXEN, R. 1932. Ist die Buche die «Nährmutter» des deutschen Waldes. Forstarchiv 8.

VAN SLYKE and J. FOLCH, 1940. Manometric carbon determination. J. Biol. Chem. 136.

VIRO, P. J., 1955. Investigations on forest litter. Commun. Inst. for. Fenn. 45. 6.

WIEDEMANN, E., 1951. Ertragskundliche und waldbauliche Grundlagen der Forstwirtschaft. Teil III. Frankfurt a.M.

WIJKSTRÖM, T., 1935. Metoder för undersökning av fodermedels mineralbeståndsdelar. Medd. nr. 459. Centralanst. försöksv. jordbr. Stockh. Avd. lantbrukskemi, nr. 56.

WITTCH, W., 1933. Untersuchungen in Nordwestdeutschland über den Einfluss der Holzart auf den biologischen Zustand des Bodens. Mitt. Forstwirtsch. Forstwiss. 4.

WITTICH, W., 1936. Der Einfluss der Lärche auf den biologischen Zustand des Bodens. Z. Forst- u. Jagdw. 68.

WITTICH, W., 1939. Untersuchungen über den Verlauf der Streuzersetzung auf einen Boden mit Mullzustand. Forstarchiv 15.

WITTICH, W., 1943. Untersuchungen über den Verlauf der Streuzersetzung auf einem Boden mit Mullzustand II. Ibid. 19.
WITTICH, W., 1944. Untersuchungen über den Verlauf der Streuzersetzung auf einem Boden mit Mullzustand IV. Ibid. 20.
WITTICH, W., 1953. Untersuchungen über den Verlauf der Streuzersetzung auf einem Boden mit starker Regenwurmtätigkeit. Schriftenr. forstl. Fak. Univ. Göttingen, No. 9.

# Mengde og kjemisk sammensetning av strøet i lerke,- bøke-, gran- og furubestand og dets virkning på jordbunnen.

## Innledning og oppgavestilling.

Disse undersøkelser er en direke fortsettelse av en mindre undersøkelse i Ås 1948—49. Resultatene herfra var såvidt interessante at arbeidet ble fortsatt og utvidet slik at materialet nå foreligger fra i alt 6 felt.

Bakgrunnen for undersøkelsene er den diskusjon som har vært ført siden midten av forrige århundre om de forskjellige treslags jordforbedrende eller jorddegenererende evne. Lerk har svært ofte i denne forbindelse vært trukket frem som et meget gunstig treslag med et rikt strøfall, mens gran av mange har vært betraktet som jorddegenererende og råhumusdannende. Resultater fra forskjellige tidligere undersøkelser gir imidlertid ikke noen entydige svar på disse spørsmål. Det kan også være meget usikkert å trekke paralleller for vårt land med resultater og erfaringer fra andre breddegrader, og vi har derfor med denne undersøkelse søkt å belyse saken litt nærmere.

Følgende treslag er undersøkt:

Europeisk lerk *(Larix decidua)* i Grue prestegårdsskog, Grue,

sibirisk lerk *(Larix sibirica)* i Østreng skog, Eidsberg, Ringsaker prestegårdsskog, Ringsaker og ved Øvergård, Koppang i Storelvdal,

japansk lerk *(Larix leptolepis)* i Norges Landsbrukshøgskoles skog, Ås,

bøk *(Fagus silvatica)* i Norges Landbrukshøgskoles skog, Ås og i Fritzøehus park, Brunlanes.

For alle felter unntatt Ås er det lagt ut sammenligningsfelter i nærstående gran- eller furubestand for derved å få så ensartede jordbunnsforhold som mulig.

I tabellene 1 (s. 121) og 2 (s. 123) er skjematisk oppsatt de forskjellige data som inngår i felt- og bestandsskrivelsen.

Undersøkelsene omfatter årene 1951—52 og 1952—53, i Ås også 1948—49. Formålet med dem kan kort sammenfattes slik:

1. Hvilke strømengder produserer lerk og bøk årlig?
2. Hvilke mengder av næringsstoffer inneholder dette strø?
3. Hvor fort omsettes det?
4. Hvilken virkning på jordsmonnet har strøet fra lerk og bøk?
5. Hvordan er ovennevnte forhold for lerk og bøk sammenlignet med forholdene for våre vanlige treslag gran og furu?

Det er i arbeidet behandlet forskjellige kategorier av strø, som er gitt følgende definisjoner:

1. *Skogstrø* er alt det organiske materiale som i løpet av året tilføres jordbunnen fra trærne.
   a. *Hovedstrø* er nåler eller løv fra hovedtreslaget i de bestand som undersøkes.
   b. *Reststrø* er alt annet strø fra hovedtreslaget (kvister, kongler, bark osv.).
   c. *Annet strø* er skogstrø som ikke skriver seg fra hovedtreslaget.
2. *Bunndekkestrø* er strø fra bunnvegetasjonen.

## Metodikk.

Innsamlingen av strøet er gjort ved hjelp av samlekar og -kasser. I de aller fleste bestand ble det satt ut 30 kar i regelmessig kvadratforband med 5 m avstand. Det er tatt nøye hensyn til å få jevn bestandstetthet og god avstand til bestandskanter. Bl. a. av disse grunner har det enkelte steder vært nødvendig med en gruppevis fordeling av innsamlingskarene.

Bortsett fra feltene i Ås, hvor den første undersøkelsen ble gjennomført 1948—49, ble samlekarene satt ut sommeren 1951. Forsøket ble avsluttet i marken 2 år etter, sommeren 1953. Etterhvert som strøet ble samlet inn, ble det tørket ved værelsestemperatur. Hvert års strøfall i hvert kar ble sortert i de tre fraksjoner «hovedstrø», «reststrø» og «annet strø». Hver fraksjon ble så veiet særskilt for hvert kar. Prøvene ble malt på kvern og analysert. For strøkategoriene «reststrø» og «annet strø» ble dette gjort sams for hvert bestand. Hovedstrøet ble imidlertid før malingen slått sammen i grupper etter karenes plasering i bestandet. Disse grupper ble analysert hver for seg og er brukt som enkeltobservasjoner under den tallmessige behandling av materialet. Følgende stoffer er bestemt: kalsium, magnesium, mangan, kalium, fosfor, kvelstoff og kisel.

For om mulig å få et begrep om total mengde uomsatt hovedstrø i strøsjiktet, ble det tatt ut blokker på 0,1 $m^2$ av strølaget og den øverste del av humusen, 4—5 fra hvert bestand. Alt hovedstrø med godt bevart struktur ble utsortert, tørket og veiet.

Fra de samme blokker ble bunndekkestrøet frasortert, unntatt moser. Disse prøver ble malt og analysert særskilt for hvert bestand.

I hvert bestand er beskrevet 4 eller 5 jordprofiler, og jordprøver for analyse er tatt fra alle sjikt i hvert profil. Jordprøvene er forbehandlet ved sikting gjennom 2 mm sikt.

Det er i alle bestand foretatt måliger og aldersbestemmelser som grunnlag for beregning av grunnflatesum og volum samt for bonitering.

### Mengden av årlig tilført strø.

I tabell 3 (s. 132) er oppført de tørrstoffmengder av de forskjellige kategorier skogstrø som i forsøksperioden er tilført jordbunnen i de undersøkte bestand, og av tabell 4 (s. 133) fremgår den prosentiske fordeling av disse kategorier. Som man ser er det overalt hovedstrøet som spiller den største rolle. Bare i meget få tilfeller utgjør dette mindre enn 70 prosent av det totale strøfall fra trærne, og det ser stort sett ut til at det spiller en større rolle hos gran enn hos lerk.

Når det gjelder de tilførte vektmengder, veksler disse ganske meget fra år til år i samme bestand. Det er heller ingen klar entydighet med hensyn til hvilket treslag som er den største strøprodusent.

Det er sikkert flere forhold som spiller inn når det gjelder strøproduksjonen. En av de faktorer som antakelig betyr mest, er tettheten. I figur 1 (s. 131) har vi satt strømengdene i forhold til grunnflatesummen for de enkelte bestand. I noen tilfeller er bestandene delt opp i grupper. På figuren er også tatt med noen resultater fra Morks arbeid om strøfallet (MORK 1942). Selv om grunnflatesummen ikke er noe fullgodt uttrykk for tettheten ser det likevel ut til å være ganske god sammenheng.

### Totalt strøforråd i strøsjiktet.

Som nevnt har vi prøvet å få et begrep om hvor fort strøet fra de forskjellige treslag blir omsatt. Metoden er temmelig grov, og man bør ikke legge alt for stor vekt på de absolutte tall. Resultatene er satt opp i tabell 5 (s. 135). Usikkerheten ved dem kommer også til syne i den relativt høye middelfeil.

Totalt strøforråd satt i forhold til det årlige strøfall, ligger gjennomgående høyere under gran enn under lerk, og høyere under lerk enn under furu og bøk. I Brunlanes ligger det høyere under bøk enn under gran.

### Kjemisk innhold i strøet.

I tabell 6 (s. 138) er oppført resultatene av den kjemiske analyse av hovedstrøet for de forskjellige år. De oppførte tall gjelder innhold i prosent av tørrstoff. De samme resultater er tegnet opp i søylediagrammene i figurene 2, 3 og 4 (s. 140—44). Det er ved hjelp av

Students t-test regnet ut om den forskjell i kjemisk sammensetning vi finner er statistisk sikker.

Når det gjelder lerk og gran er resultatene for kalsium helt entydige. Grannåler inneholder overalt betydelig mer kalsium (Ca) enn lerkenåler, mens forholdet er omvendt for magnesium (Mg). Kiselinnholdet (Si) er stort sett høyest i lerkenåler, mens det for kvelstoff (N), mangan (Mn), kalium (K) og fosfor (P) ikke er noen klar tendens.

Selv furunåler er i våre forsøk vel så kalsiumrike som lerkenålene på samme felt. Bemerkelsesverdig her er også det meget lave innhold av kisel i furunålene. Furunålene har ellers stort sett også lavere innhold av de øvrige undersøkte stoffer.

For undersøkelse av forholdet bøk-gran har vi også bare ett felt å bygge på. Av resultatene herfra ser en at bøkebladene er rikere på kalsium og magnesium enn grannålene, men fattigere på kalium, fosfor og kvelestoff.

Også i Ås viser det seg at lerkenålene er relativt fattige på kalsium, og for samtlige stoffers vedkommende ligger bøkebladene høyere, til dels ganske betydelig.

Tabell 7 (s. 142) viser analysetallene for mineralstoffenes prosentiske innhold i asken. I tabell 11 (s. 156) og 12 (s. 157) er oppført det kjemiske innhold i «reststrø» og «annet strø». Disse strøkategorier er til dels temmelig forskjelligartet, og har langt større variasjon i kjemisk sammensetning enn hovedstrøet. Gjennomgående er det fattigere på næringsstoffer, men det er dog flere unntagelser.

Det er ganske betydelige «gjødselmengder» som hvert år tilføres jordbunnen med skogstrøet. I tabell 13 (s. 158) er satt opp hva som hvert år er tilført med «hovedstrø» og «reststrø» — altså samlet strømengde fra hovedtreslaget — i de undersøkte bestand. Tallene gjelder kg pr. ha. Det er selvfølgelig også her meget store variasjoner fra år til år og mellom de forskjellige treslag. Som rimelig kan være ligger Storelvdal lavest. Stort sett er det kvelstoff som blir tilført i størst mengde, i et par tilfeller over 40 kg pr. ha. Både kalsium og kisel kommer høyt opp. Bemerkelsesverdig er de relativt store mengder mangan som tilføres med strøfallet.

**Bunnvegetasjonen.**

Vi har prøvet å få et mål for størrelsesordenen av bunndekkestrøet. Resultatene finnes i tabell 14 (s. 161). Da det innsamlede materiale her er såvidt sparsomt, skal man selvfølgelig ikke legge for meget vekt på resultatene. Vi har heller ikke prøvet å få noe mål for hva som tilføres fra mosedekket, som jo mange steder utgjør en viktig del

av bunnvegetasjonen. Vi finner derfor ikke grunn til å gå noe særlig i detalj på dette punkt.

Det er imidlertid verdt å merke seg at bunnvegetasjonen i de undersøkte bestand synes å ha relativt liten vektmessig betydning som strøkilde. Av størrelsesorden ser det ut til at den kommer omtrent på samme nivå som «annet strø». Det er også tydelig at bunnvegetasjonen spiller en langt større rolle i lerkebestand enn i granbestand.

Når det gjelder næringsinnhold ligger strøet fra bunnvegetasjonen ganske høyt, og de tilførte mengder næringsstoffer blir relativt store.

Dette forhold virker sikkert inn, og kompliserer en undersøkelse hvor man søker å sette strøfall fra trærne i relasjon til jordbunnsforholdene.

## Jordbunnsforhold.

Det er foretatt en temmelig grundig beskrivelse av jordbunnsforholdene. Resultatene av de kjemiske analyser er satt opp i tabell 8 (s. 146). Tallene for pH viser den vanlige tendens til stigning nedover i profilet. Videre er det en meget god sammenheng mellom innholdet av organisk stoff (glødetapprosent) på den ene side og M-tall som er et uttrykk for kaliuminnholdet, og L-tallet for fosforinnholdet på den annen side. Samme tendens gjør seg også gjeldende for innholdet av lettoppløselig kalsium.

Mekanisk sammensetning av undergrunnen er ført opp i tabell 9 (s. 148). Jordartsinndelingen i tabell 1 (s. 121) er gjort på grunnlag av denne.

De virkninger et bestemt treslag har på jordbunnen vil først komme tilsyne i humusen. Det er derfor satt opp en spesialtabell for denne, tabell 10 (s. 150), hvor forskjellene mellom de to bestand på hvert felt er regnet ut.

Av tallene for pH fremgår det at lerkehumusen i de undersøkte bestand er mindre sur enn gran- og furuhumusen. Lerkehumusen er fattigere på kali, og i de fleste tilfelle på fosforsyre, kalsium og uorganisk fosfor enn gran- og furuhumus, mens den er rikere på organisk fosfor og kvelstoff. Den siste rubrikk i tabell 14 angir forholdet mellom kullstoff og kvelstoff. Når denne kvotient er høy, viser dette at nedbrytningen av det organiske materiale foregår tregt, mens en lav kvotient tyder på en rask nedbrytning. Resultatene skulle her tyde på at nedbrytningen i lerkehusmusen foregår noe raskere enn i gran- og furuhumusen, raskere under gran enn under bøk i Brunlanes, og raskere i bøkehumusen enn i lerkehumusen i Ås.

Bortsett fra feltet i Storelvdal med lerk og furu stemmer dette godt med beregningen av omsetningshastighetene i tabell 5.

Det er stor forskjell i C/N-forholdet på de forskjellige felter. Storelvdal og Grue som har de laveste boniteter, har høyest C/N-forhold.

## Diskusjon og konklusjon.

pH, organisk fosfor og C/N-forholdet er vanligvis betraktet som gode indikatorer på humustilstanden. Hvis disse legges til grunn for bedømmelse av humusen i de undersøkte bestand, synes det å være en tendens til at humusforholdene er gunstigere under lerk enn under gran og furu. For bøk er materialet mindre, men resultatene tyder ikke på at det er noen vesentlig forskjell mellom dette treslag og gran, mens humustilstanden i Ås synes å være bedre under bøk enn under lerk.

Det må dog her påpekes at de forskjeller som er funnet ikke alltid er statistisk sikre. Videre må man merke seg at de registrerte forskjeller er av langt mindre størrelsesorden enn den forskjell man finner fra felt til felt, og som må tilskrives de stedlige forhold. Undersøkelsen viser i det hele tatt at man skal være meget varsom med å stemple et treslag som «jordforbedrende» eller «jorddegenererende» bare på grunnlag av strømengder og strøkvalitet. Sammenholder man tidligere undersøkelser, fremgår det også tydelig hvordan disse forhold kan veksle fra sted til sted og fra år til år.

Det er rimelig å anta at de kjemiske forhold i jordbunnen vil ha innvirkning på strøets sammensetning. Vi har imidlertid ikke i vårt materiale kunnet påvise noen sammenheng, bortsett fra humusen, men på dette punkt er det vanskelig å skille mellom årsak og virkning.

Man skal heller ikke se bort fra den mulighet at det for treslagene kan være forskjeller mellom artene innenfor samme slekt, kanskje like store som mellom helt forskjellige treslag. Det foreliggende materiale fra Ås med japansk lerk, sammenholdt med resultatene for sibirisk og europeisk lerk, kan tyde på at den førstnevnte kanskje er dårligere strøprodusent enn andre lerkearter.

Et treslags virkning på jordbunnen avhenger sikkert også av bestandskarakteren. Når f. eks. lerk så ofte er ansett som særlig gunstig, skyldes dette sannsynligvis ikke minst lerkebestandets åpne stilling. Lys, varme og nedbør slipper til i langt større utstrekning enn i et granbestand. Dette gir muligheter for en rik bunnvegetasjon som kan gi verdifult strø, og omsetningen av alt strø foregår raskt, slik at man får gode humusforhold.